ALTERNATIVES TO THE USE OF LIVE ANIMALS IN MILITARY MEDICAL TRAUMA TRAINING

A thesis presented to the Faculty of the U.S. Army Command and General Staff College in partial fulfillment of the requirements for the degree

MASTER OF MILITARY ART AND SCIENCE
General Studies

by

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The use of masculine pronouns in this thesis is gender immaterial.

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

ALTERNATIVES TO THE USE OF LIVE ANIMALS IN MILITARY MEDICAL TRAUMA TRAINING, by Major David S. Galloway, 160 pages.

Trauma training is regularly conducted within the military medical community in an environment of increasing scrutiny and pressure to replace animals with inanimate alternatives. This thesis uses the Advanced Trauma Life Support (ATLS) animal laboratory as the basis of evaluation to answer the question: Can nonanimal alternatives replace the use of animals in military medical trauma training?

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LIST OF ABBREVIATIONS

AAALAC	Association for Assessment and Accreditation of Laboratory Animal Care
AAM	Anthropanalogous Model
ACS	American College of Surgeons
AR	Animal Rights
ATLS	Advanced Trauma Life Support
AVAR	Association of Veterinarians for Animal Rights
AW	Animal Welfare
AWA	Animal Welfare Act. The Animal Welfare Act, 7 U.S.C. 2131-2158, amended (1970, 1976, 1985, 1990) which is implemented by USDA Regulations 9 CFR. Parts 1-4.
AWIC	Animal Welfare Information Center
C4	Combat Casualty Care Course
CAD	Cadaver
CARL	Combined Arms Research Library
CFR	Code of Federal Regulations
CIM	Complex Interactive Mannequin
CIRO	Clinical Investigation Regulatory Office
CTM	Combat Trauma Management
DOD	Department of Defense
DTIC	Defense Technical Information Center (Database)
ETS	Event-Totality Standard
FEDRIP	Federal Research in Progress (Database)
IACUC	Institutional Animal Care and Use Committee
IO	Institutional Official
IVD	Interactive Videodisc

GAO (USGAO)	U. S. General Accounting Office
NPM	Nonphysical Model
NRC	National Research Council
NRPM	Nonrealistic Physical Model
PCRM	Physicians Committee for Responsible Medicine
PETA	People for the Ethical Treatment of Animals
PHS (USPHS)	US Public Health Service
RDTE	Research, Development, Testing, and Evaluation
SFMS	Special Forces Medical Sergeant (Military Occupational Skill: 18D)
USDA	US Department of Agriculture
VR	Virtual Reality

CHAPTER 1

INTRODUCTION

Animal facilitated trauma training is regularly conducted within both the civilian and military medical communities. This thesis addresses the issue of animal use in trauma training, answering the question: Can nonanimal alternatives replace the use of live animals in military medical trauma training? It outlines the requirement for military trauma training, the controversy surrounding the use of animals in trauma training, and the potential alternatives to the use of animals in trauma training. This thesis focuses on the Advanced Trauma Life Support (ATLS) practicum, or ATLS-like events, that are the model for military trauma labs. Evidence collected via literature search was analyzed to determine the characteristics of available training models and the ability of these models, individually or collectively, to replace the use of animals in trauma training laboratories. This thesis may be used as a guide in the planning and conduct of trauma procedure laboratories. While it cannot replace the training director's responsibility to personally search for and consider alternatives to the use of animals in trauma training, it may reduce the subjectivity of model selection, acceptance, and use through the deliberate identification, characterization, and analysis of trauma training models. The intended audience of this thesis is those individuals who are already conducting animal facilitated trauma training or those who are considering it. This audience should be well grounded in the regulation, vocabulary, and issues surrounding animal use in training. For others with an interest in the subject, separate appendices discussing the alternative concept (appendix A), the current ethical context of animal use in training (appendix B), and animal use regulation and the animal use approval process (appendix C) are provided as background material.

Background

Animal Use in Training

Animal laboratories have traditionally been used in medical education to teach surgical procedures and for research. In 1543, Vesalius' *Fabrica* offered the first published description of animal use in medical training (Swindle 1984). This account details the use of a pig in experimental surgery, as well as the performance of two resuscitative skills common to today's animal labs: thoracotomy and tracheal intubation (using a reed). More recently, use of the horse for wound investigation was reported by the French army in 1907 (Schantz 1979). The use of cats for intubation training was described in the early 1970s (Calderwood and Ravin 1972; and Jennings et al. 1974). As early as 1980, George L. Sternbach, Joel L. Mattsson, and others reported the conduct of comprehensive animal laboratories for trauma training at the University of California, the University of Chicago, and within the military. In the 1980s, animal labs became an established means of training resuscitative skills and an integral component of ATLS, medical certification courses, and emergency medicine residency programs (Olshaker et al. 1989). The military continues to use animals in medical trauma training to develop and validate critical lifesaving skills and to maintain skill proficiency at various levels in the casualty treatment chain. The most notable uses are in emergency medicine residency programs, the Combat Casualty Care Course (C4), the Special Forces Medical Sergeant's (SFMS) Course, and Advanced Trauma Life Support (ATLS) courses for physicians, nurses, physician's assistants (PAs), and other primary healthcare providers.

Animal Use Controversy

Animal use in research and education has been a topic of increasing debate in the past decades.[1] The use of live animals in medical trauma training is an extraordinarily controversial issue because of the nature of some of the procedures performed (especially wounding) and the

fact that these exercises are terminal events for the animals used. Animal advocacy organizations have made animal use a nationwide, front-page issue. Most outspoken among these is the People for the Ethical Treatment of Animals (PETA). PETA has a wide audience and has had significant impact in forwarding the Animal Rights movement. "PETA operates under the simple principle that animals are not ours to eat, wear, experiment on, or use for entertainment" (PETA n.d.c). Their activities include lobbying, education, and investigation. Their impact on public awareness of the issues and animal use legislation must be acknowledged. However, their impact within the academic community has been limited because they have not published in scholarly literature. Other organizations, such as the Physician's Committee for Responsible Medicine (PCRM) and Association of Veterinarians for Animal Rights (AVAR), take a more scholarly approach. They offer well written, academic, and convincing arguments for the use of alternatives and the disuse of animals in trauma and surgical training. They offer practical and ethical arguments against animal use in research, offer suggested alternatives to the use of animals in medical education, and call for trauma training reform (PCRM 1999). They claim that the use of realistic mannequins, simulators, and human cadavers improves anatomical landmark recognition and is less expensive than live animal use (Barnard and Hogan n.d.). These arguments cannot be ignored.

The impact of anti-vivisectionist organizations has been manifested in increased public awareness of the issues, reassessment of the ethical context of animal experimentation, and reevaluation of animal facilitated trauma-training programs. The American College of Surgeons (ACS), who once required completion of the live animal practicum for ATLS certification, now allows alternative laboratories on a preapproved basis (Hughes 2000). Military animal use is under especially heavy scrutiny. As recently as 1998, Congress ordered a General Accounting Office (GAO) audit of all DOD Animal Use programs focusing on applicability to military needs, unnecessary duplication of efforts, and incorporation of appropriate alternative methods (GAO

1999). In the past two decades, the atmosphere governing the use of animals in trauma training has changed from one of permissiveness to one of scrutiny and qualified use. Directors of trauma training courses are hard pressed to clearly demonstrate the necessity for animal use in their training programs. Articulation of this need requires an understanding of trauma training events, psychomotor skill development, and the roles that available animate and inanimate models play in the development of the proficient battlefield trauma responder.

Context

The Need for Trauma Training

The American College of Surgeons (ACS) notes that trauma is the leading cause of death among Americans in the first four decades of life (ACS 1997). In the battlefield hospital, traumatic injury accounts for nearly 100 percent of the patients treated. The relatively young and healthy patient base served by the military healthcare system provides limited opportunities for military healthcare providers to manage traumatic cases. A survey of Gulf War medical readiness revealed that "only 2 of 16 surgeons on a naval hospital ship had recent trauma surgical experience" (GAO 1998b, 2). The inability to train military healthcare providers in the management of traumatic patients is a national security concern and poses unique problems for the medical departments of the armed forces. In their 1998 Report to Congress, the General Accounting Office concluded that "military medical personnel have almost no chance during peacetime to practice their battlefield trauma care skills. As a result, physicians both within and outside the Department of Defense (DOD) believe that military medical personnel are not prepared to provide trauma care to severely injured soldiers in wartime, which could result in the loss of life and limbs" (GAO 1998b, 2). To remedy this deficiency DOD has initiated exchange programs with civilian trauma centers such as the Defense Medical Readiness Training Institute's

(DMRTI) Joint Trauma Training Center (JTTC) and the Joint Special Operations Medical Training Center's (JSOMTC) Emergency Medical Technician (EMT) externships.

JTTC offers military trauma teams a 30-day training rotation at a major trauma center in order to improve trauma skills and medical readiness (JTTC n.d.). This program focuses on training the surgical trauma team in a hospital environment; first responder training is currently beyond its scope. Many healthcare providers, especially medics, require first responder training to prepare them for their battlefield roles and to meet civilian certification requirements. The JSOMTC EMT externship program is an example of the incorporation of ambulance ride-alongs and emergency room exposure into the training of medics. This program conducts two separate one-month externships in order to increase the exposure of their medics to real-life trauma scenarios and to satisfy requirements for National Registry of Emergency Medical Technicians certification (Tangney 1998). JTTC and JSOMTC are the only two formal on-site training experiences offered to military healthcare providers today.

Placing military healthcare providers in such high volume trauma centers offers experiential training in the management of emergent patients beyond the scope of their exposure in military medical facilities. In theory, and in practice, experiential training is preferred. It allows primary healthcare providers to practice valuable wartime skills on real patients, with real wounds and life-threatening emergencies, in a predictable, high intensity environment. However, this program fails to meet total training needs due to availability and credential requirements. Trauma center programs simply do not have the capacity to meet the trauma training needs of the military. Similarly, the military cannot afford widespread use of trauma training center programs without abandonment of their daily duties and decreasing the availability of healthcare to soldiers.

Credential requirements dictate that healthcare providers be certified before they treat patients within a given institution. The credentials of professionals are their licenses and postgraduate training certificates. The fact that professional licenses from one state are often not

reciprocal in other states can limit training opportunities. Medical paraprofessionals establish their credentials through programs such as Advanced Cardiac Life Support (ACLS) and Emergency Medical Technician-Paramedic (EMT-P) that allow them to render treatment within their limited scope of practice. These credentials are likewise often limited by state boundaries. Formal programs such as the JTTC and the JSOMTC help eliminate credentialling problems, but these programs have very limited capacity in comparison to the training requirement. These problems limit the utility of trauma training center programs to prepare the entire healthcare team for their wartime mission. The majority of military healthcare providers requiring training cannot hope to receive emergency case management experience in trauma centers.

Given a shortfall in experiential training access and availability, one method of ensuring the development and maintenance of necessary trauma management skills is to create appropriate training situations in a "classroom" environment. Trauma procedure laboratories allow for the instruction and practice of manipulative procedures, many of which are infrequently performed yet critical to the practice of emergency medicine, in a controlled environment. Well-structured, scheduled trauma exposure allows for the most efficient use of the soldier's time and the military's resources. It also makes trauma management training available to a much larger healthcare provider population. Such exposure is routinely provided via animal facilitated trauma training exercises such as ATLS. Numerous studies by Doctor Jameel Ali and others show the effectiveness of such programs in terms of improved patient care and demonstrate that even single exposures to trauma skills training can have positive impact in decreasing patient mortality (Ali, Cohen, et al. 1998). The military uses trauma-training exercises such as the ATLS practicum for the development, validation, and maintenance of proficiency in critical trauma management and resuscitative skills. While this animal use amounts to 35 percent of all DOD animal use programs (GAO 1999), it accounts for less than 2 percent of the animals used in the conduct of DOD animal facilitated research and training (DOD 1996).

Trauma Training Events

The ACS began conducting the ATLS course in 1978, in response to deficiencies in the treatment of trauma patients. The course is designed to standardize and improve the treatment of trauma patients during that first "golden hour" post injury. This course has met tremendous success and is emulated worldwide (ACS 1997). Most Army medical courses conducting animal labs follow an ATLS-practicum model. These exercises may be strictly procedural or may involve trauma management scenarios. Procedural training generally follows the ATLS animal laboratory closely, while patient trauma management scenarios require the assessment, stabilization, and evacuation of an injured patient under simulated battlefield conditions. These training events have improved healthcare provider confidence and proficiency in specific, highly perishable, critical lifesaving skills.

All animal facilitated trauma-training scenarios begin with anesthetizing and preparing the patient-animal. While the military almost exclusively uses goats for these labs, the ACS allows the use of other species such as dogs or pigs in their ATLS practicums (ACS 1997). Veterinarians and technicians oversee the conduct of all animal facilitated training events to ensure that the animals maintain a surgical plane of anesthesia in order to preclude pain or distress. The ATLS practicum is a highly structured, ACS regulated, training event in a controlled classroom-laboratory environment. Animals used in ATLS practicums have received no traumatic wounds since the intended training is strictly procedural. To encourage participation by all and increase hands-on learning, the ATLS practicum calls for a student to animal ratio of four student-physicians per animal. The ATLS animal laboratory usually involves the individual conduct of six resuscitative procedures under the close supervision of a surgeon, certified by the ACS to instruct the ATLS laboratory.[2] Upon completion of the procedures, the animal is euthanized. The training event usually lasts for two hours. Other, ATLS-like, events are common.

They are also controlled classroom exercises, using similar procedures, but they do not confer ACS sanction or certification.

While the ATLS program has proven beneficial in the management of civilian trauma, battlefield trauma is more complex and requires additional training (Baker 1994; and Bellamy 1984, 1987). Military modification of the ATLS program reflects differences in combat and civilian[3] "casualty care in three areas: the nature of the injuries (penetrating over blunt), the organization of the military medical system, and the conditions of practice on the battlefield (danger, austerity, casualty density, treatment goals, and inclement weather)" (Zajtchuk 1995, 39). Combat Trauma Life Support (CTLS) (Baker 1994; Blumenfeld et al. 1997; Ekblad 1990; Heydorn 1990; and Kluger et al. 1991), and British Army Trauma Life Support (BATLS) (Eaton et al. 1990) are military trauma programs designed to address these deficiencies. However, these variants, much like ATLS, are classroom programs designed to improve cognitive and procedural knowledge of trauma. Combat trauma management (CTM) scenarios are designed to test application of this knowledge through the stabilization and treatment of injured animal-patients.

CTM scenarios usually involve the treatment of a multiply wounded patient in a simulated battlefield environment. Again, the scenario begins with an anesthetized, prepared patient-animal, and with veterinary personnel on hand to oversee the welfare of the animal. This event is less structured than the ATLS practicum, allowing a variation of wounds and environments to complicate patient management and increase training realism. Wounds may include ballistic penetration, extremity fracture, or lacerations (Knudsen and Darre 1996). Life threatening wounds usually create arterial hemorrhage, since exsanguination is by far the single greatest killer on the battlefield. CTM is designed to verify proficiency in patient stabilization and the management of life threatening wounds. It requires the student to accurately assess, resuscitate, and treat the wounded patient. The student to animal ratio for CTM is usually low (1:1 to 3:1). CTM is much rarer than the ATLS, or ATLS-like, scenarios and requires from two to

eight hours to complete. Again, all trauma-training scenarios are terminal events. The animal, having been anesthetized throughout the entire procedure, is euthanized upon completion of the exercise.

While experiential training, such as a trauma center training program, is the preferred method of training for the management of combat casualties, it is not available to the entire military healthcare team. Historically, combat trauma training has included the use of animals to increase the availability and realism of this essential training (Berlin 1969; Berlin et al. 1969; and Lisitsyn 1971). Animal facilitated trauma training continues to be a mainstay of military medical preparation for the treatment of combat casualties. Such courses are an invaluable tool to guarantee the military healthcare provider's proficiency and confidence in his ability to treat combat casualties (Blumenfeld et al. 1997). While program directors search for the best methods to train military healthcare providers in critical lifesaving skills, animals continue to play a critical role in the development and maintenance of proficiency in these skills.

The Alternatives Concept

The alternatives concept is not new, although it has received increased attention in the past two decades.[4] In 1959, the concept of alternatives was offered as the 3Rs: Replacement of animals with nonanimal models; Reduction of the numbers of animals used; and Refinement of methods in order to reduce animal pain and distress (Russell and Burch 1959; and Kreger et al. 1998). The intent of the 3Rs is the elimination of avoidable pain and minimization of unavoidable animal suffering. While replacement of each animal use by a inanimate model is the goal; this is not always possible without degrading the outcome of the event. Doctor Cathy L. Greenfield (1994, 23) defines the criteria for alternative use: "an alternative is acceptable for teaching if it allows the student to reach at least the same level of proficiency as obtained when the same procedure is taught in a traditional [animal model] manner."

Legally and ethically, the use of animals in trauma training requires the search for alternatives to the painful procedures performed on those animals and implementation of those alternatives found to offer comparable training value to the use of the animal. The use of alternatives in trauma training does not imply the total replacement of animal use; refinement and reduction activities also reduce animal suffering. Maximizing the number of students trained on a single animal leads to a reduction in the number of animals used. The use of modern anesthetic agents and techniques is a refinement that reduces animal pain. Ensuring that students are sufficiently skilled to benefit fully from the experience of animal facilitated training is a refinement as well as a reduction, because highly trained students make fewer mistakes, inflict less pain, and waste fewer animals. All of these efforts have decreased total animal suffering.

The alternatives concept is misunderstood even by many who refer to it regularly. The emphasis of the concept is not on the elimination of animal use, but on the elimination of avoidable animal suffering. The subtle misunderstanding of this most basic aspect of the alternative concept leads Animal Rights activists to demand the elimination of animal use in medical research, testing, and education. This misunderstanding also leads medical educators and trainees to fear alternatives to animal use in training rather than to see them as an opportunity to improve technical skills. Models are available which, if used appropriately, have the potential to improve the total learning experience of trauma training events. Most of these models are already in use by the military.

Alternatives to Animal Use in Trauma Training

Bruce W. Pince (1970) made the first systematic attempt to define and compare models of the human body for the study of trauma in impact sensitivity (blunt trauma). He categorized human "simulations" into 4 types: man, anthropanalogous devices, animals, and nonphysical models. This study will similarly classify nonanimal simulations for human trauma treatment

training: Nonphysical Models (NPM), Nonrealistic Physical Models (NRPM), Anthropanalogous Models (AAM), Cadavers (CAD), and Complex Interactive Mannequins (CIM).

Nonphysical Models (NPM). NPMs have no "physical dimension, but are real only in a conceptual sense" (Pince 1970, 234). Interactive videodisc (IVD), computer simulation (CS), and virtual reality (VR) are examples of NPMs. Lectures, discussions, presentations, or other forms of didactic instruction are not NPMs. This author considers these activities mandatory preparation for training with animals or nonanimal alternatives; they are not alternatives themselves.

Nonrealistic Physical Models (NRPM). NRPMs are models that are not anatomically accurate. They are frequently referred to as "models" or "jigs" in the literature. Examples are the use of oranges for training hypodermic injection, plastic tubing for training venipuncture, or broken wooden boards for training fracture stabilization. Few NRPMs are commercially available and most are "home-made."

Anthropanalogous Models (AAM). AAMs are anatomically realistic physical models, frequently called "mannequins" or "dummies." AAMs may replicate the entire human body, traumatized or intact, or parts of the human body such as the arm or head. Common examples are intubation dummies or catheterization arms. AAMs may also simulate specific anatomic parts such as bones for fracture stabilization training. Many AAMs are commercially available.

Cadavers (CAD). A cadaver is a dead body intended for scientific use. In this thesis the term "cadaver" is used to refer to any nonliving tissue, human or nonhuman, fresh or prepared, whole body or part. Thus, embalmed human bodies, fresh pigs' ears, chicken legs, and freeze-dried pork intestines are all categorized as cadavers.

Complex Interactive Manikins (CIM). CIMs are a type of AAM. They are categorized separately from AAMs due to their complexity and advanced capabilities. These mannequins are computer operated, interactive, responsive to intervention, and offer realistic life signs and

programmable scenarios. Examples are the human patient simulators used extensively in anesthesia training.

The term "alternative" is not synonymous with the term "replacement;" it more appropriately connotes improvements to a given animal use. In education, using the training model with the most educational benefits and fewest training detractors constitutes improvement. An assessment of the various models of the trauma patient, whether animate or inanimate, and use of the most appropriate model for each level of training or educational objective, will result in the optimal training event.

The Research Question

The proceeding discussion has outlined the requirement for military trauma training, the controversy surrounding the use of animals in trauma training, the trauma training events, and the potential alternatives to the use of animals in trauma training. This background allows a reasonable exploration of the central question of this thesis. The primary research question is: Can nonanimal alternatives replace the use of live animals in military medical trauma training? The secondary questions are:

1. What is the value of using live animals in trauma training?
2. What nonanimal alternatives are available for use in trauma training?

The question of animal use in trauma training is really one of necessity. Central to the argument of the necessity for animal use in trauma training is the benefit derived from that use in the training event. If unique benefits are not derived from the use of animals in trauma training, then the use cannot be ethically justified. Similarly, if inanimate alternatives to animal use can be substituted without the loss of training value, again the use cannot be justified. The benefits of animal facilitated trauma training in light of alternatives that might exist for the proposed animal

use must be explored. By answering these questions, conclusions as to the necessity of animal use in trauma training can be made.

Assumptions

Many animal protection groups offer opposition to the use of animals in training based on sanctity of life or animal rights arguments. In this paper, I make a basic assumption of species superiority: that sacrifice of animal life to improve human conditions can be ethically justified. I assume that justified animal use is ethical and acceptable. This assumption is consistent with existing animal use legislation and ethical mores.

Animal facilitated trauma training has received very little academic attention, while the topic of surgical skills training offers more published discussion. Both of these disciplines involve the development of specialized psychomotor skills, and surgical training develops skills similar to those required to treat traumatically injured patients. I acknowledge that differences exist between the two disciplines; the greatest of these is that of urgency. Skills learned in surgical labs may be first performed on human patients in a controlled, highly supervised, operative environment.[5] Some opportunities for this type of supervised, progressive training are also available in trauma training, such as learning to intubate in the context of routine anesthesia patient care. However, the performance of trauma procedures generally must be immediate, offers little time for instruction, and is difficult to justify delegation to a less experienced individuals. Two dilemmas of trauma training are that procedures must be well trained before anticipated use and most procedures are used infrequently, but critical when needed (Sternbach and Rosen 1977; and Nelson 1990). The demand for first time, independent (unsupervised), proficient performance is greater in the training of trauma related skills than that required in surgical training. The first required use of trauma skills is likely to be more akin to solo flight than a pre-solo check ride. Despite these noted differences in these two disciplines, their educational methods are similar. I

assume that conclusions drawn from the study of surgical training are applicable to trauma skills training, and this thesis will use surgical training evaluations as evidence.

Experiential training is accepted as the best method to prepare for the treatment of traumatic patients. Animal facilitated training is considered as an alternative to experiential methods because circumstances preclude its use. Additionally, experiential training and animal facilitated training may be used to augment one another. For example, the SFMS course integrates classroom instruction, experiential training, and animal facilitated training to produce the best combat medic in the world. During 12 months of medical training, the SFMS candidate will conduct 2 separate one-month externships in medical centers (Tangney 1998). I assume that, when animal facilitated trauma-training protocols are approved, experiential training has been considered and is unavailable.

Limitations

The primary limitation to this research is that no comparative studies have been conducted to assess the use of animate or inanimate models in trauma training. Ideally, trials that evaluate and compare the acquisition of trauma skill proficiency between groups trained via animal facilitated means and via inanimate alternative means would be available. This is not the case; no such trails have been conducted. Additionally, only limited numbers of evaluations are available concerning the training of individual resuscitative or surgical skill procedures using animate and inanimate models. The manuscripts available are usually descriptive in nature. The few model evaluations or comparisons that exist generally use student perception surveys or graded observation as the evaluation criteria. The validity, reliability, and consistency of this type of subjective evaluation are debatable. Additionally, these evaluations generally attempt to validate an instructional method rather than a specific model. Michael S. Bauer and Howard B. Seim (1992) offer that such head-to-head model evaluation is difficult because students do not

enter the study with comparable psychomotor abilities and objective criteria for the evaluation of training outcomes across different models are elusive. The difficulty, cost, and necessity of animal use to perform such evaluations are limiting. Given different starting points and the difficulty of defining evaluation criteria between models, only endpoints can be evaluated. Currently, even the evaluation of these endpoints is subjective.

Lack of trials demonstrating objective data lend to a content analysis and comparative methodology in this thesis. While conclusions and recommendations will be made, they will be comparative in nature and lack the objectivity of statistical significance. Pince (1970, 232) noted in his own trauma model evaluation that "a 'review of reviews' is limited by lack of a common comparative standard. Only the use of such a common standard allows objective evaluation of the costs and benefits associated with each simulator." This analysis will also be plagued by fallible judgment. However, the chosen methodology is designed to eliminate, as much as possible, such subjectivity.

Delimitations

The primary delimitation in this thesis is limiting the analysis to replacement alternatives. Trauma training is a terminal event for the animals involved. Only alternatives that, individually or collectively, replace the event are considered. Alternatives which replace the need to perform individual procedures on the animal, but which do not replace all of the procedures, do not replace the need to use the animal. Few would choose to train a procedure using a plastic model, when an animal is being used for the rest of the exercise.[6] The totality of the event must be considered – either the animal use is replaced, or not. Alternatives that refine and reduce the number of animals, while important topics for discussion, do not eliminate the animal use. The consideration of student qualifications, anesthetic efficacy, and appropriate instrumentation use is expected. Increased student to animal ratio and protocol sharing will help decrease the absolute

number of animals used. I assume that these issues are considered. While refinement and reduction alternatives in animal facilitated trauma training are necessary, they do not address the central issue of replacement. When opponents to animal use address alternatives, they mean replacement. Investigator justifications of animal use in trauma training must also hinge on arguments of replacement--the inability of a given model or set of models to replace the proposed animal use. This is the regard in which alternatives will be viewed in this thesis as well.

Similarly, this thesis will not address the use of animals as a part of integrated programs. The integrated use of multiple instructional techniques (didactic, IVD, CS, models, animals, and clinical exposure) is an accepted educational method. Many surgical trainers promote the use of animal models in training in order to complement other training strategies (Carpenter et al. 1991; Kopchok et al. 1993; Wolfe et al. 1993; Bohm and Milsom 1994; Clerici 1995; and Gardiner et al. 1996). The question in this thesis is not one of how animate and inanimate models might best complement each other, but one of how they might replace each other. The use of animate and inanimate models to complement each other will be indirectly validated by this thesis because this is a logical and accepted teaching modality. However, this thesis will specifically address replacement and not complementation.

The scope of this study is limited to the initial individual training of primary healthcare students in basic prehospital resuscitative skills. Topics such as surgical trauma training, trauma team training, and skill retention training are not addressed. The targeted student population includes paraprofessionals (medics) and professional healthcare providers (physicians, PAs, and nurses) who do not routinely encounter trauma. Nontrauma team members of field hospitals may also be called upon to perform these skills in the event of overwhelming casualties (mass casualty situations). Advanced trauma training for this population can positively impact casualty care (Mattsson et al. 1980; and Pons et al. 1985). Mattsson and others (1980, 401) found that

"paramedics with advanced training in selected trauma management techniques can significantly enhance the probability of survival of military casualties."

The skills required by these students to appropriately treat an injured patient include patient assessment, patient stabilization, and invasive resuscitative procedures. Pre-hospital programs such as cardiopulmonary resuscitation (CPR) and Advanced Cardiac Life Support (ACLS) are designed for uniquely civilian crisis scenarios and train only minimally invasive resuscitation skills such as intubation, venipuncture, and chest compression. Most DOD medical personnel are certified to perform minimally invasive resuscitation. Pre-hospital combat trauma management often demands invasive resuscitative procedures such as chest decompression or surgical airway placement, as well. Models used in civilian pre-hospital programs may or may not be appropriate for training the skills required of military medics due to the requirement to perform these invasive procedures. This study focuses on training to this higher standard of pre-hospital capability.

The collection of evidence for this thesis consisted of a literature search concerning the use of models and methodologies in the instruction of human and veterinary trauma and surgery. While the literature search permitted no specific exclusions of specific model types or subspecialties within these areas; certain disciplines and model types are excluded from this analysis due to their inapplicability to this topic. References to physiologic models were ruled-out as evidence because these models are designed to develop cognitive elements rather than derive psychomotor benefit. As a class, NPMs to include IVD, CS, and VR were excluded from the analysis. These models lack the physical dimension necessary to play a significant role in psychomotor skill development. The surgical disciplines of microsurgery and indirect (endoscopic) surgery were also ruled-out in evidence collection. The procedural skill set required for trauma treatment is represented well by open surgery, but poorly portrayed by these two disciplines. These delimited topics were included in the literature search because they contain

references to other simulations. They are discussed in chapter 2 to an extent that their lack of bearing on this subject is demonstrated. However, they were not addressed specifically as possible alternatives to animal use because these models are not capable of training the skill set required by trauma first responders.

Significance

Animal use has moved from the realm of a medical right to a medical privilege. Privileges can be taken away if they are abused, or if there is perception of abuse. Military animal use receives heavy scrutiny from a Congress under pressure to decrease military spending, and under pressure from constituents who oppose animal use. Animal facilitated training, along with all military laboratory animal use, is at risk if proper measures are not taken to justify and articulate the necessity of each proposed animal use. Doctor David English notes that it is the responsibility of medical educators to "routinely question and offer justification for any use of animals in medical education" (English 1989, 43). The GAO (1999) has noted a systemic problem in the identification, documentation, or implementation of possible alternative uses within DOD. The current problem is not one of inadequate justification, but one of adequate articulation of that justification. The danger in poorly articulating alternative considerations is that it lends to public perceptions of inadequate forethought, research, and planning, or of outright abuse of animal use privileges.

While the regulation of animal use has not changed significantly in the past decade, awareness of the issue has. In the past, the medical community, both civilian and military, has permitted animal use in training as a de facto necessity. Animal facilitated trauma training protocols have regularly been approved based the declaration of animal-use necessity by a committee (for example the ACS) or a high-ranking individual. Such justification--the animal use is needed it because someone in authority says so--is simply no longer acceptable. Each animal

use must be justified and considered on an individual basis. Individual justifications will contain much of the same reasoning that a committee such as the ACS's Subcommittee on Trauma might use to require a practicum for completion of the ATLS course. However, each investigator must clearly articulate his argument for the use of animals in his own training event. This justification is based upon his unique student population, their level of previous training, animate and inanimate model availability, and his educational objectives. The articulation of his consideration of animal and nonanimal alternative model use clearly defines the necessity of animal use in his trauma course.

No longer can Army medical researchers propose the use of animals, nor Institutional Animal Care and Use Committees (IACUCs) approve protocols, especially controversial trauma-training protocols, based on de facto medical necessity. Definitive evaluation of the actual benefits derived from such animal use and the possible use of nonanimal alternatives is required before researchers can label such uses necessary. This thesis is written to aid trauma trainers in their animate or inanimate model considerations and their animal use justification process. It will serve as a guide for those already conducting animal facilitated trauma training, or those now considering it, in their evaluation and justification of the necessity of live animals in their training programs. By reducing the subjectivity of the selection, acceptance, and use of models in trauma training, it will assist in the planning and conduct of trauma procedure laboratories. Most importantly it should assist trauma trainers in their articulation of the above.

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1. This topic is discussed in greater detail in appendix B.

2. The standard ATLS procedures are as follows: Cricothyrotomy, Diagnostic Peritoneal Lavage, Pericardiocentesis, Needle Thoracotomy, Tube Thoracotomy, and Venous Catheterization via Cutdown.

3. The leading cause of life threatening civilian trauma is vehicular accidents (blunt trauma).

4. For a more detailed discussion of the alternative concept see appendix C.

5. The praetorian system is based on gradually increasing participation and responsibility thorough observation, assistance (limited participation), and primary performance phases of surgery.

6. This could be argued in terms of decreased invasiveness, but is not practical.

CHAPTER 2

LITERATURE REVIEW

Introduction

The literature search conducted to gain evidence on the topics of alternative and animal use in trauma training was performed using multiple databases accessed through DIALOG.[1] The search targeted the topics of ATLS, human and veterinary surgical instruction, animal models, and alternative models. Since the ATLS practicum is the prototype event for animal facilitated trauma training, this topic was researched to determine the benefit of the animal procedure practicum in ATLS. Veterinary and human surgical instructional literature discusses medical training, the development of psychomotor skills, and the use of animate and inanimate models in training. Animal model descriptions discuss the use and impact of animal models in experimental surgery and training. Finally, inanimate model descriptions document the existence and use of nonanimal alternatives in surgical and trauma training. The search for inanimate models was both general and specifically focused on certain trauma skills: airway management, peritoneal lavage, pericardiocentesis, wound management, chest decompression, and venous access. A bibliographic scrub of full text journal articles and an Internet search uncovered additional important citations. Literature by groups such as PCRM and AVAR, advocating reform in surgical and trauma training, government sites, and commercial model manufacturer sites are accessible via Internet. In total, the search uncovered nearly five hundred manuscripts for evaluation.

Review of the Topical Literature

Most of the literature concerning this topic comes from professional medical journals. A review of the literature reveals no clinical trial or prospective study comparing the use of animate and inanimate models in trauma training laboratories. Ideally, publications would offer studies comparing the mortality rates of patients treated by medics trained on animals to the mortality

rates of those treated by medics trained using alternate methods. Such studies do not exist. Out of nearly five hundred manuscripts reviewed, only fourteen specifically address the subject of model use in trauma training. A limitation of these articles, which is consistent throughout all the literature reviewed, is that they are generally descriptive in nature, and evaluation or comparison of animate or inanimate models is rare.

Several authors discuss the use of animals in trauma procedure laboratories (Sternbach and Rosen 1977; Sims 1979; Mattsson et al. 1980; Thompson et al. 1984; Olshaker et al. 1989; Homan et al. 1994; Knudsen and Darre 1996; and Tortella et al. 1996). George Sternbach and Peter Rosen (1977) describe the use of animals for training emergency medicine residents at the University of Chicago. They provide a detailed discussion of each of the resuscitative procedures performed: cricothyrotomy, tracheotomy, tube thoracotomy, open thoracotomy, cardiac repair, aortic clamping, venous cutdown, peritoneal lavage, and exploratory laparotomy. They conclude that the animal laboratory "does produce instrument facility and technical deftness resulting in increased confidence with which a physician can assume human patient responsibilities" (545). J. K. Sims (1979) describes the pilot program conducted as validation of the ATLS practicum to include a discussion the performance of common resuscitative procedures. B. M. Thompson and others (1984), and B. J. Tortella (1996) only offer brief descriptions of their animal use laboratories.

Joel Mattsson and others (1980) and Peter Knudsen and Eric Darre (1996) provide detailed descriptions of animal facilitated trauma procedure laboratories conducted by the military. Mattsson describes the conduct of resuscitative procedure laboratories as part of medical physician training. Knudsen and Darre describe the conduct of a multi-echelon Danish military medical training event (Operation Exercise) which incorporates the treatment of a wounded animal-patient. This is the only article available that discusses using wounded animals for training. It is also the only published description of animal facilitated trauma training in which the

lab focuses on whole patient assessment, stabilization, and treatment, rather than the instruction of isolated procedures. Both articles offer valuables discussion of the advantages of using animals in trauma training and detailed descriptions of the conduct of resuscitative procedures. Mattsson and others also discuss the prerequisite level of student preparation for animal facilitated trauma training, noting that "access to the animal laboratory should be limited to those prepared for advanced training," since the lab is best suited to refinement of previously learned skills, and gaining speed and confidence (401).

Jonathan S. Olshaker and others (1989) and Clark S. Homan and others (1994) describe the conduct of studies to determine the ability of animal laboratories to improve the confidence and proficiency of physicians performing resuscitative procedures. Olshaker and others (1989) use semi-quantitative analysis to document a significant increase in the confidence level and procedural competence of the students, and conclude that the swine laboratory is a valuable training opportunity. Homan and others (1994) assess tube thoracotomy training success using a canine model. This study demonstrates that improvement, in terms of increased speed, is directly correlated to repetitive practice. The continued reduction in time scores during day eighteen reevaluation indicates skill retention and value in conducting follow-up labs. Finally, the authors suggest that a single opportunity to practice chest tube placement (such as during ATLS) may be inadequate to attain clinical proficiency. Both articles conclude that animals continue to play a critical role in assuring competency in life-saving procedures.

The use of cadaver models in resuscitative procedure laboratories is discussed by M. E. Weaver and others (1986), Brian D. Eaton and others (1990), and Marc S. Nelson (1990). Weaver and Nelson discuss the use of human cadavers in a resuscitative procedure workshop. Nelson (1990) offers an outstanding discussion of the advantages and disadvantages of the different models used in emergency skill training. He describes cadaver use in detail to include procedures for which the human cadaver is an excellent, fair, and poor model. Eaton and others (1990)

discuss the use of animal cadavers in the conduct of British Army Trauma Life Support, noting that British law allows the use of neither live animals nor human cadavers in the conduct of such training. Each article describes cadaver preparation to add realism and learning value, as well as deficiencies of the cadaver model.

J. M. Klausner and others (1987), Amir Blumenfeld and others (1997), and the Physicians Committee for Responsible Medicine (PCRM) (1997) offer varied alternative models that can be used in trauma training. Klausner and others (1987) briefly outline training aids that are available to allow centralized and efficient trauma training to include video tapes, slides, mannequins, computer simulations, and animal laboratories. They include a paragraph length discussion of the use of animal laboratories, which echoes the comments of Mattsson and others (1980) and Sternbach and Rosen (1977). Blumenfeld and others (1997) describe a military variant of the ATLS program designed by the Israeli Defense Force. Combat Trauma Life Support (CTLS) is designed to improve care of the wounded soldier in the pre-hospital setting. Included in the paper are pictures and descriptions of NRPM use for training airway management and chest decompression. Simulation of fracture splinting is practiced on a student-patient's leg. Finally, PCRM (1997) offers cadaver and inanimate model alternatives for each of the ATLS procedures currently performed on animals. The ACS has authorized conduct of such alternative laboratories on a pre-approved basis and is investigating wider incorporation of these labs into their program (Hughes 2000). The article gives points of contact for cadaver and simulator suppliers. This article is not peer reviewed and makes unqualified statements about cost savings and physician preferences that detract from its informative nature. Despite possible bias, this article provides valuable information for trauma trainers.

Other Literature Consulted

ATLS and Variants

The topic of ATLS, and related trauma life support courses, was reviewed in order to find descriptions or evaluations of the animal practicum that is performed during these courses. This effort proved relatively unproductive. The few descriptions of animal use in such courses are noted above. No article provided analysis of the benefit of conducting an animal laboratory during these courses. The benefit of the ATLS course is clearly demonstrated in numerous studies by Jameel Ali, Rasheed U. Adam, Paul E. Collicott, and others. Over one hundred of these papers appear in the reference list.[2] The need for and conduct of military variants of the ATLS program is also discussed.[3] However, none of these articles addresses the value of having conducted an animal laboratory as part of the course.

Surgical Instruction

Literature concerning human and veterinary surgical instruction was reviewed in order to find descriptions of animate or inanimate model use in training. These articles also provide background knowledge of the principles of psychomotor skill development The assumption that those conducting trauma training intuitively understand educational psychology and optimal psychomotor training methods is inaccurate. Knowledge of these principles is essential since they define the most advantageous use of each model in trauma training. Review of surgical instruction literature reveals that course directors have great latitude in choosing methods that will enhance the development of psychomotor skills in their students, but that the accepted principles of psychomotor skill acquisition must be incorporated into their training program.

In "The development of motor skills in orthopedic education," Joseph A. Kotpa (1971b) applied the motor-skill principles introduced by Paul M. Fitts and Michael I. Posner (1967) directly to the development of procedural psychomotor skills for surgery. He concluded that

students demonstrate surgical psychomotor skill at three levels: cognitive, integrative, and autonomous. These same phases apply directly to the development of resuscitative procedure psychomotor skills. Understanding the components of procedural skill development, as summarized in table 1, helps trainers to break down trauma skills into components that are best taught using different methodologies or models.

TABLE 1
SKILL DEVELOPMENT LEVELS

Level	Attributes	Goals
Cognitive	Rote Memorization Mental Imagery	Knowledge Surgical Anatomy Performance Steps (Sequencing) Indications / Contraindications Instrumentation
Integrative	Repetition Feedback	Hand-Eye Coordination Dexterity Overlearning
Autonomous	Challenge Problem-Solving Clinical Realism	Independence Confidence Competence Delicate Motor Skills

The cognitive level of development is a mental learning phase. At this stage, learning is through rote, memorization, and mental imagery. The goal of this level is to develop an understanding of the required procedures to include performance step sequencing, surgical principles, techniques, indications, contraindications, medical decision making, and instrument recognition and selection criteria. Dane M. Chapman (1994) argues that four types of learning are essential to procedural skill acquisition: (1) memorization of critical steps and sequential order, (2) rule using such as indications and contraindications, (3) visual cue recognition allowing instrument selection, and (4) psychomotor coordination. The first three of these four fall within the cognitive phase of psychomotor development. Having attained this knowledge the student

will be able to plan and perform a procedure by breaking it down into tasks or steps, but lacking appropriate motor skill development, his approach will be deliberate and inflexible. His performance can be followed as if he were verbalizing the steps; many will lip or verbalize at this stage. Cognitive training enhancers include any training methods that improve material presentation and retention.

"One of the biggest fallacies in training surgeons appears to be the notion that if a prospective surgeon cognitively understands a procedure, he will be able to perform that procedure in the operating room. This simply is not the case. Stopping at the end of the cognitive stage does not permit psychomotor skill acquisition" (Kaufman et al. 1987, 3). Lectures, presentations, demonstrations, or interactive computer sessions do not develop psychomotor skills, and even if students have acquired some motor ability, cognitive methods do not offer enough tactile and visual stimuli to produce procedural retention. Mastery of techniques and procedure sequencing can only be ingrained in a manual trial-and-error manner (Kopchok et al. 1993; Maroon and Gosling 1973; and Bauer and Seim 1992). Hands-on practice is a logical and necessary next step in psychomotor skill development.

The integrative level combines the cognitive aspects of decision making with manual dexterity. The goal of this phase is the development of hand-eye coordination to augment the knowledge obtained during the cognitive level of training (Christopherson et al. 1986). Despite the fact that psychomotor performance at this level will be improved and more fluid, it still tends to be irregular, and task steps are easily identified.

The key to success in the integrative phase is the repetitious practice of basic skills (McLaughlin and Iserson 1986; and Klausner et al. 1987). Joseph A. Kopta (1971b) encourages distributed practice, as opposed to mass practice, in order to discourage muscle fatigue and encourage reflective improvement. Surprisingly, a set of six basic motor skills is consistently recommended for integrative level psychomotor development: knot tying, instrument handling,

ligation, suturing technique, dissection, and incision (Kopta 1971b; Lossing, Hatswell, et al. 1992; Greenfield et al. 1995; Olsen et al. 1996; and Stotter et al. 1986). Repetition of basic skills can be monotonous, but motivation can be maintained by demonstrating the clinical applicability of these basic exercises (Greenfield et al. 1994). Applicability and meaningfulness of the laboratory experience have also been shown to increase retention (Kaufman et al. 1987).

Supervision and feedback are also important to minimize error prone activities that will ingrain inappropriate motor habits. Feedback is provided both by instructor critique and haptic realism (appropriate tactile sensation). Overlearning,[4] which is continued practice after a skill is learned to enhance retention, is encouraged. Ann T. Stotter and others (1986) noted that more mechanically naive students showed greater relative improvement during the integrative phase of training, but also had a more difficult transition to the autonomous level and the clinical setting. This would indicate that overlearning is also a goal during this phase of training.

Development at this level is enhanced by basic motor skill practice in an appropriate learning environment. Too much stress makes it hard to concentrate on learning essential skills (Rosin 1986). A vicious cycle occurs in which stress and anxiety cause inattention, which leads to poor performance and frustration. This cycle makes learning difficult (Forbes et al. 1989). Additionally, a "highly stressful learning environment is an invitation for the development of error patterns in motor behavior" (Kopta 1971a, 382). Michael S. Bauer, N. Glickman, L. Glickman, and others (1992, 79) described the ideal basic skills laboratory: "students become motivated to learn when provided an environment where risks can be taken, where tasks can be manipulated to be challenging (not too easy and not too difficult), where the student is actively participating and where peer interaction is possible." Stress should be graded throughout the development of the student. Later, during the autonomous stage, stress is essential to familiarize the student with sensations such as urgency and to encourage confidence in his ability to perform under stressful conditions.

The autonomous level is a progressive development of skill and ability out of the integrative stage. The goal of training is for students to perform at the autonomous level of psychomotor development. At this level, psychomotor skills are "locked-in" and require no conscious effort. Performance is smooth, automatic, and resistant to environmental distractions or stress. F. C. Spencer (1983) and Joseph Kopta (1971b) both note that seventy-five percent of procedural performance is decision making and reaction to unexpected situations such as individual patient variations or complications. The other twenty-five percent, which is composed of psychomotor performance, should be fully mastered so that the operator's full attention can be devoted to the critical task of decision making. This defines the autonomous level.

During the autonomous level, the goal is to develop the student's confidence, independence, and competence geared towards terminal task performance (Olsen et al. 1996). Training is focused on advanced skills or the integration of basic skills into complicated procedures. Appropriately challenging cases, problem-solving practice, and clinical realism will enhance student development. Challenging cases help to improve problem-solving skills while reinforcing autonomous psychomotor behavior. Final psychomotor development requires a training environment that closely resembles the anticipated terminal performance event, especially in terms of anatomy, environment, and potential complications (Chapman 1994). Clinical realism, to include anatomic variation, poor visualization, environmental distracters, and urgency, increases the challenging nature of the training and increases both student motivation and confidence.

Albert Bandura, who forwarded the precept of "efficacy expectation," found that the motivation to perform a task and the success of terminal performance are positively related to the student's perception of self-efficacy--a student who is confident in his ability to perform, will perform (Bandura and Schunk 1981). In a prospective clinical study, M. Cobley and R. S. Vaughan (1992) found that prior experience with difficult intubations led to greater success in

securing airways in emergency situations and suggested the creation of simulated difficult airways in training. In a similar study, Daved W. Van Stralen and others (1995) found that paramedic students, who were not comfortable with basic techniques, performed more poorly when presented with technically difficult procedures. These studies support Andranik Ovassapian's (1983) conclusion that confidence is an essential attribute to successful autonomous level performance.

The requirement for structured, progressive programs based on the principles of phased psychomotor development is advocated both in instructional literature and clinical papers. C. M. Nicks and others (1986) documented the benefit of progressive, systematic instruction for surgical residents. Their research revealed that supervised practice during basic skill laboratories provided optimal development of student technical skills and significantly impacted the procedural competency of the students. They also discovered that inadequate preparation for operatory experiences had a negative impact on skill development. In another study, George F. Snell (1978) concluded that basic motor skill learning (suturing on pigs' feet) was not a worthwhile learning experience unless it was followed by progressive experiences. This finding was based on the students' failure to retain skills during a period of surgical inactivity, while practicing students' skills improved.

Finally, psychomotor development training is not complete until students have been tested for competency (Maroon and Gosling 1973). Robert Matz (1989, 396) demands both confidence and competence be demonstrated before providers are allowed to treat patients noting that "lives have been lost while relative novices whose belief in their competence . . . bolstered by a few practice runs on a corpse or manikin have wasted . . . precious minutes." Structured and progressive psychomotor development begins with a definition of learning objectives, progresses through the cognitive and integrative levels into the autonomous phase, then ends with testing for competency. It is commonly agreed that structured, progressive training is the best way to

develop procedural psychomotor skills in students, ensuring their preparedness for terminal performance.

The adoption of these principles is witnessed in the change of surgical training methodologies from procedure-based to skill-based instruction. Surgical exercises once presented as whole procedures are now taught as a collection of discrete, trainable tasks. This trend is seen in both human and veterinary medical instruction. A generalized lack of basic skills has been noted in surgical students (Stotter et al. 1986; Reid and Vestrup 1988; Smeak 1989; and Smeak et al. 1991). Renewed emphasis on basic skills accounts for the increasing popularity of craft workshops and procedure laboratories, even among skilled practitioners (Lippert et al. 1975; Bevan 1981, 1986; Lippert and Farmer 1984; Weaver et al. 1986; Barnes 1987; Lewis and Nusbaum 1987; Jones and Thompson 1988; Hill and Kiff 1990; Lossing, Hatswell, et al. 1992; and Powers and Draeger 1992). These same lessons are applicable to trauma training. By defining training objectives and applying the principles of psychomotor skill development, trauma course directors can appropriately select those training models that enhance learning in their students. Ann L. Johnson and James A. Farmer (1989, 12) noted that the most important conclusion to be gained from their studies "was the need for the appropriate model in the appropriate situation."

Animal Models

Descriptions of animal use in surgical instruction and trauma training were evaluated to determine characteristics that offer advantages or act as detractors in the education of students. When analyzed within the context of the principles of surgical instruction outlined above, these characteristics define the appropriate roles of animal models in trauma training--their niche.

Discussions of the use of animals in trauma training have already been addressed (Sternbach and Rosen 1977; Sims 1979; Mattsson et al. 1980; Thompson et al. 1984; Klausner et al. 1987; Olshaker et al. 1989; Homan et al. 1994; Knudsen and Darre 1996; Tortella et al. 1996;

and ACS 1997); however, substantial information regarding the value of animals in training can also be gained through the evaluation of discussions of animate surgical models. Animals have been used for surgical instruction in U.S. medical schools for over 100 years (Swindle 1984). Surgical model discussions were found in the literature of three disciplines: experimental surgery, human surgical training, and veterinary surgical training. The use of dogs, cats, primates, goats, rabbits, ferrets, poultry, horses, cattle, and sheep in training is summarized in table 2.

Trauma training laboratories use larger animals (dog, pig, and goat) to more closely approximate the size of humans and to allow the use of human medical instruments. Apart from trauma procedure laboratories, the single greatest use of animals is for intubation training. Cat (Calderwood and Ravin 1972; Jennings et al. 1974; and Woods et al. 1980), dog (Sternbach and Rosen 1977; and Mattsson et al. 1980), pig (Forbes et al. 1989; and Knudsen and Darre 1996), and ferret (Powell et al. 1991) use has been described. Additionally, the use of cats as a model for pediatric tracheotomy (McLaughlin and Iserson 1986) has been described.

Discussions of animals in experimental surgery tend to be descriptive. The use of the pig has largely replaced the use of the dog as the model of choice for experimental surgery. Although the pig is an excellent model for many experimental and training procedures, this change is largely a reflection of budgetary issues and mounting social and regulatory pressures (Woakes and Cranwell 1977; Kerrigan et al. 1986; Horneffer et al. 1986; Cameron et al. 1994; Swindle 1983a, 1983b, 1984, 1986; Swindle and Smith 1988; Anders et al. 1989; Gormley 1990; and Gholson et al. 1990).

In human surgical training the most commonly described model is the dog (Woods et al. 1980; Watson et al. 1982; Christopherson et al. 1986; and Lossing, Hatswell, et al. 1992). Other models include the rabbit (Gimpelson et al. 1989) which is especially suited for urogenital surgerical training, the pig (Swindle 1983a, 1983b), and poultry (Tugsel 1992). Veterinary surgery reports the use of the dog (Rosin 1986; Carpenter et al. 1991; Greenfield et al. 1994;

Bauer, Glickman, Glickman, et al. 1992; Greenfield et al. 1995; and Olsen et al. 1996), the rabbit (Boothe and Hartsfield 1990; and Kaplan and Timmons 1979), and large animals (Shires 1986).

TABLE 2
ANIMAL MODELS USED IN TRAINING

Model	Use	Citation
Feline	Intubation Training	(Calderwood and Ravin 1972)
Feline	Intubation Training	(Jennings et al. 1974)
Canine	Resuscitative Procedures Lab	(Sternbach and Rosen 1977)
Swine	Surgical Training	(Woakes and Cranwell 1977)
Primate	ATLS Practicum	(Sims 1979)
Rabbit	Veterinary Surgical Training	(Kaplan and Timmons 1979)
Varied Species	Trauma Research	(Schantz 1979)
Canine	Resuscitative Procedures Lab	(Mattsson et al. 1980)
Canine / Rabbit / Feline	Surgical Training Lab	(Woods et al. 1980)
Canine	Surgical Training	(Watson et al. 1982)
Canine	Surgical Training	(Gay 1983)
Swine	Surgical Training	(Swindle 1983a)
Swine	Surgical Training	(Swindle 1983b)
Canine	ATLS Practicum	(Thompson et al. 1984)
Canine / Swine	Surgical Training	(Swindle 1984)
Swine	Experimental Surgery	(Swindle 1986)
Canine	Surgical Training	(Christopherson et al. 1986)
Feline	Tracheotomy Training	(McLaughlin and Iserson 1986)
Large Animals	Veterinary Surgical Training	(Shires 1986)
Swine	Surgical Training	(Kerrigan et al. 1986)
Swine	Surgical Training	(Horneffer et al. 1986)
Varied Species	Veterinary Surgical Training	(Rosin 1986)
Varied Species	Veterinary Surgical Training	(Gambardella 1986)
Canine	Resuscitative Procedures Lab	(Klausner et al. 1987)
Swine	Epidural Training	(Owen et al. 1987)
Canine	Experimental Surgery	(Swindle and Smith 1988)
Rabbit	Surgical Training	(Gimpelson et al. 1989)
Swine	Resuscitative Procedures Lab	(Olshaker et al. 1989)
Swine	Surgical Training	(Anders et al. 1989)
Swine	Intubation Training	(Forbes et al. 1989)
Rabbit	Veterinary Surgical Training	(Boothe and Hartsfield 1990)
Swine	Surgical Training	(Gormley 1990)
Swine	Surgical Training	(Gholson et al. 1990)
Canine	Veterinary Surgical Training	(Carpenter et al. 1991)
Canine	Veterinary Surgical Training	(Smeak et al. 1991)
Ferret	Intubation Training	(Powell et al. 1991)
Canine	Veterinary Surgical Training	(Bauer, Glickman, Glickman, et al. 1992)
Canine / Swine	Surgical Training	(Lossing, Hatswell, et al. 1992)
Canine	Veterinary Surgical Training	(Rosin 1992)
Poultry	Surgical Training	(Tugsel 1992)
Canine	Resuscitative Procedures:	(Homan et al. 1994)
Canine	Veterinary Surgical Training	(Greenfield et al. 1994)
Canine	Thoracotomy Training	(Chapman et al. 1994)
Swine	Surgical Training	(Cameron et al. 1994)
Canine	Veterinary Surgical Training	(Greenfield et al. 1995)
Canine	Veterinary Surgical Training	(Olsen et al. 1996)
Goat Lab	Resuscitative Procedures Lab	(Tortella et al. 1996)
Swine	Resuscitative Procedures Lab	(Knudsen and Darre 1996)
Swine	Thoracotomy Training	(Chapman et al. 1996)
Swine / Dog / Goat	ATLS Practicum	(ACS 1997)

Birger Schantz (1979) discusses many aspects of model selection for experimental missile trauma wounding which make the discussed species (horses, cattle, small ruminants, dogs, and pigs) more or less suitable for this research. The technical aspects of his discussion, such as selection of the animal with the skin best replicating human skin, are beyond the scope of this thesis. However, this discussion, along with similar model critiques by others (Sternbach and Rosen 1977; Woakes and Cranwell 1977; Kaplan and Timmons 1979; Mattsson et al. 1980; Loew 1982; Gay 1983; Swindle 1983a, 1983b, 1984, 1986; Swindle and Smith 1988; Kerrigan et al. 1986; Horneffer et al. 1986; Zrunek et al. 1988; Boothe and Hartsfield 1990; Powell et al. 1991; Chapman et al. 1994; Cameron et al. 1994; and Chapman et al. 1996) are invaluable to trauma trainers who must consider such issues in their own model selection. These authors note that there is not one best animal model for the simulation of man and that careful consideration must be given to the choice of the most appropriate model. The correct choice of the appropriate animate or inanimate model is entirely dependent on the objectives of the learning event. This is just as true for trauma training as it is for trauma investigation.

Inanimate Models

The literature was searched in order to identify, characterize, and analyze nonanimal alternatives being used in surgical or trauma training. Inanimate model descriptions were evaluated, similarly to animate model uses, to determine their training advantages and disadvantages. When compared to the characteristics of animal models and analyzed within the context of the principles of surgical instruction, these characteristics also define a niche for each inanimate model category.

Nonphysical Models (NPM)

Nonphysical models include interactive videodisc (IVD), computer simulation (CS), and virtual reality (VR) technologies. Despite their future potential, NPMs currently have no

significant role in integrative or autonomous level psychomotor development and are not considered suitable alternatives to the use of animals in trauma training.

Interactive Videodisc and Computer Simulation. Computer based simulations have had great success as learning tools in physiology and pharmacology laboratories (Hartmann 1990; Ammons 1995; Barnard et al. 1988; HSUS 1999; and Bauer 1993). The current trend is towards IVD/CS use as a replacement for the live animal models once used in these laboratories. Comparative studies demonstrate that IVD/CS is a comparable learning model to animals in these laboratories and, hence, an appropriate replacement for this animal use (HSUS 1999). These same computer programs are used to enhance physical training models (AAMs and CIMs) in order to increase trauma training realism. Computer simulation has also proven successful as a training tool for medical decision making, medical leadership, and trauma team evaluation (Henry and Waltmire 1992). IVD/CS are well suited to provide students with instruction at every level of learning and are designed to increasingly challenge students to progress to higher levels of cognitive learning.[5] Despite these educational advantages, IVD/CS technologies are intended for only cognitive learning and play an insignificant role in the development of basic or advanced psychomotor skills.

Computer aided instructional technologies can greatly enhance learning and decrease time spent at the cognitive level of psychomotor development. Because they present "information in a nonlinear fashion using text, still pictures, video film sequences, and sound," they maintain student interest and increase learning (Pearce 1990). Computer games have been used to improve the hand-eye coordination of surgical students (Bauer and Seim 1992). IVD auto-tutorial use in veterinary surgical instruction has replaced animal laboratories for the instruction of gowning, gloving, surgical preparation, basic instrument use, surgical anatomy, surgical steps, and surgical decision-making (Bauer 1993). Joseph V. Henderson and others (1986) documented the success of IVD instruction for teaching patient assessment algorithms and clinical decision making during

CTLS training. Additionally, Brian W. Garcia of the Air Force Institute of Technology (1996) has developed a virtual emergency room simulation for medical emergency training. Computer aided instruction enhances the development of procedure sequencing, mental imaging, and medical decision making skills. Computer simulation also aids in the instruction of visual cue recognition (Chapman 1994). Accessibility, interactivity, and repeated student use of IVD/CS enhance cognitive learning (Klausner et al. 1987). Nevertheless, IVD/CS technologies lack the haptic elements required to obtain psychomotor skills (Smeak 1989; and Chapman 1994). IVD/CS play little role in the development of basic or advanced psychomotor skills, and they are not considered further as viable alternatives to animal use in this thesis.

Virtual Reality. Virtual reality (VR) is an immature technology with tremendous potential to change trauma training methods. The advantages of VR training systems are numerous. They will allow repeated practice in a low risk environment. They will also provide performance feedback by recording procedures for review. VR can be used to isolate and overtrain select procedural sequences or be used for competency testing applications. They can be programmed to incorporate anatomic variation and unexpected scenarios, or to offer unusual complications (Higgins et al. 1995; Meglan 1996; Higgins et al. 1996; and Merril 1997a). "Fully immersive, augmented reality simulations of battlefield trauma treatment training are under development" (Meglan 1996, 37). VR training devices will likely replace the use of animals in surgical and trauma training.

Flight simulators, which use VR to train individual pilots and flight crews, are commonplace today. Many individuals familiar with this technology are impatient for similar training to be implemented for surgical and trauma treatment personnel. While surgical simulation has benefited tremendously from the development of flight simulation, these two applications vary considerably in range of difficulty. Virtual flight simulation is technically simple; virtual surgery is significantly more complex and offers many challenges (Higgins et al.

1995; Meglan 1996; Higgins et al. 1996; Merril 1997a; Barnes et al. 1997; and Lange 2000). During flight simulation the terrain is fixed and rigid, and the airplane does not interact with environment except during failure scenarios (crashes). On the other hand, surgical terrain is dynamic, and interaction is the goal. Organs must be deformable and react with appropriate physical responses such as bleeding. These responses dramatically change the surgical landscape. Additionally, each instrument must interact appropriately with the tissues: scalpels cut while forceps hold. Sophisticated anatomic models and imagery resolution technologies are currently available; however, provision of appropriate feedback and haptic fidelity is especially challenging. In 1997, HT Medical's Gregory Merril (a, 5) noted that this level of realism remains "an elusive goal, largely considered impossible with the current technology."

The Department of Defense has taken the lead in the sponsorship of medical VR development. HT Medical Systems, Incorporated, has worked under DOD contract on projects to include the Shattered Kidney Simulation, the HT Abdominal Trauma Simulator (ATS), and the Virtual Trauma Training Environment. A review of the work done by HT Medical documents the rapid improvements in VR technology over the past few years (Higgins et al. 1995; Higgins et al. 1996; and Merril 1997a). MusculoGraphics, Incorporated, has developed a Limb Trauma Simulator (LTS) for the Army, which simulates venipuncture and the use of surgical instruments for the treatment of a gunshot wound (MusculoGraphics 1997). Richard M. Satava and Shawn B. Jones (1996) describe the projected integration of VR systems into military medical programs through applications involving individual training, mission rehearsal, team training, and research environments. The Combat Trauma Patient Simulator (CTPS) (STRICOM 1998) is a multi-echelon, individual and unit, medical training environment using CS, VR, and CIM technologies which offers such training opportunities. Despite the simulated use of instruments and performance of resuscitative procedures, none of these models offers the haptic fidelity to allow the training of psychomotor skills.

Virtual reality is currently used for training in indirect surgical techniques and for training experienced surgeons. Surgeons using minimally invasive techniques (scopic surgery) rely less on haptic feedback than on visual cues (Williams et al. 1990; Noar 1995a; Zeigler et al. 1995; and Ota et al. 1995). They generally perform surgery indirectly while viewing the procedure on a monitor. VR simulates scopic surgery quite well. VR simulation is also appropriate for the introduction of new techniques and advanced procedures to experienced general surgeons (MacIntyre and Munro 1990a, b). The use of the MusculoGraphics LTS or the HT-ATS are examples of instruction at this level. VR is appropriate because these "students" have already acquired advanced hand-eye coordination and are at the autonomous level of psychomotor development.

The greatest potential for near term VR use, and continued use in the future, is not in training, but in patient care applications. The interface of existing real time digital imagery (magnetic resonance imaging, computer-aided topography, and ultrasound images) with VR surgical systems will allow a patient's surgeon to perform pre-surgical planning and practice on that patient's virtual body before he steps into the operatory. Such individualized planning and preparation can significantly improve care and decrease complication rates (Higgins et al. 1996; Meglan 1996; and Rosen 1998).

Virtual reality (VR) offers many of the same cognitive advantages as IVD/CS, but suffers from a similar lack of haptic feedback. VR offers increased hand-eye interaction, but the motor interface is inappropriate for the development of basic psychomotor skills. VR also suffers from increased expense and limited availability. Currently, VR is an immature technology with tremendous potential as a trauma and surgical training enhancer. The goal of VR developers is to develop a system, which offers totally realistic visual and haptic interface (Higgins et al. 1996). Such a system would be an improvement compared to traditional instructional techniques using human or animal model patients because training opportunities would be unlimited and offer

post-procedural review. Someday this technology may be used in instruction of surgical anatomy or techniques, proficiency certification, or preoperative planning and rehearsal (Satava 1996). VR will definitely lead to reduction in the number of animals used in training, but the current reality is that VR is not there yet. One indicator that this day is fast approaching is the fact that the formal assessment of using VR surgical systems for training and evaluation has begun (O'Toole et al. 1999). Doctor Christoph Kaufmann of the National Capitol Area Medical Simulation Center equated today's VR systems with the Wright Brother's first airplane, alluding to the technology's potential despite its current immaturity (Funk 2000b). Because of these problems, VR is not applicable to integrative and autonomous level psychomotor development and is not considered further in this thesis as an alternative to live animal use in trauma training.

Nonrealistic Physical Models (NRPM)

The use of nonrealistic physical models (NRPMs) is well documented in the medical literature. Descriptions of NRPMs range from fruits (Straith et al. 1961), to ropes and rods (Johnson and Farmer 1989), to napkins (Cain and Shirar 1996). All but a handful of NRPM descriptions discuss practicing suturing techniques or knot tying. Since laceration repair is a critical combat medic skill, these model descriptions are valuable. Descriptions of NRPMs for other critical skills are few. They include two invasive airway models (Blumenfeld et al. 1997; and AMI n.d.), two venous cutdown models (Eggerston 1983; and Klofas 1997), two venipuncture models (HT 1998a; and AMI n.d.), and two chest tube models (Sinclair 1984; and Blumenfeld et al. 1997). The NRPMs, which are used for hemostasis control training, are designed for practicing vessel isolation and ligation skills and are not practical for training pressure hemorrhage control techniques (Smeak 1989; Smeak et al. 1991; Bauer and Seim 1992; and Olsen et al. 1996). The use of pieces of wood, rods, ropes, and wire to teach the principles of fracture stabilization is also described. The use of such simple, unrealistic models for the

demonstration of basic concepts and skills during the early integrative phase has proven superior to more advanced models (Lippert and Farmer 1984; Johnson and Farmer 1989; and Holmberg and Cockshutt 1994). Most NRPMs are home-made, and only a few are commercially available: Ethicon Suture Board (Ethicon 2000), Skilltray (Thomas et al. 1996), VaraDerm Skin Model (Lewis and Nusbaum 1987), CathSim Training System (HT 1998a), and Armstrong Venipuncture and Cricothyrotomy Models (AMI n.d.). NRPMs are extensively used because they are inexpensive and appropriate for use in basic skills training. The use of NRPM in training is summarized in table 3.

TABLE 3
NONREALISTIC PHYSICAL MODELS USED IN TRAINING

Model	Use	Citation
Grapefruit Skin	Wound Closure Training	(Straith et al. 1961)
Tie and Suture Board	Psychomotor Skills Training	(Boyle and Guis 1968)
Buckston Browne Aterial Jig	Anastamosis Workshop	(Bevan 1981)
St Mark's Pelvic Simulator	Anastamosis Workshop	(Bevan 1981)
Venous Cutdown Model	Venous Cutdown Training	(Eggerston 1983)
TubeThoracotomy model	Tube Thoracotomy raining	(Sinclair 1984)
Bone Models	Orthopaedic Skill Lab	(Lippert and Farmer 1984)
Varied Models	Craft Workshops	(Bevan 1986)
VaraDerm: Skin Model	Wound Closure Training	(Lewis and Nusbaum 1987)
Stoma Jig	Wound Closure Training	(Jones and Thompson 1988)
Hemostasis Model	Basic Surgical Skills Training	(Smeak 1989)
Sticks, Ropes, Rods	Psychomotor Skills Lab	(Johnson and Farmer 1989)
Abdominal Jig	Basic Surgical Skills Training	(Hill and Kiff 1990)
Ligation Jig	Basic Surgical Skills Training	(Smeak et al. 1991)
Hemostasis Model	Psychomotor Skills Lab	(Smeak et al. 1991)
Fluid Hemostasis Model	Basic Surgical Skills Training	(Bauer and Seim 1992)
Electric Suturing Board	Basic Surgical Skills Training	(Bauer and Seim 1992)
Foam Bones	Technical Skills Program	(Lossing, Hatswell, et al. 1992)
Varied Models	Procedures Workshop	(Powers and Draeger 1992)
Foam, Carpet, Yarn	Basic Surgical Skills Training	(Bauer 1993)
Varied Models	Basic Surgical Skills Training	(Greenfield et al. 1994)
Homemade Skin Model	Wound Closure Training	(Southern and Browning 1995)
Fluid Hemostasis Model	Basic Surgical Skills Training	(Olsen et al. 1996)
Electric Suturing Board	Basic Surgical Skills Training	(Olsen et al. 1996)
Perineal Tear Model	Wound Closure Training	(Cain and Shirar 1996)
"Skilltray"	Wound Closure Training	(Thomas et al. 1996)
Synthetic Bowel	Basic Surgical Skills Training	(Thomas et al. 1996)
Venous Cutdown Model	Venous Cutdown Training	(Klofas 1997)
Crico and Chest Tube Models	CTLS	(Blumenfeld et al. 1997)
CathSim Training System	Venipuncture	(HT 1998a)
Coconut & Balloon	Surgical Procedures Lab	(Anastakis et al. 1999)
Commercial Model	Venipunture Training	(AMI n.d.)
Commercial Model	Cricothyroid Training	(AMI n.d.)

Bauer and Seim (1992) describe the next generation of NRPMs. These veterinarians have developed a fluid hemostasis model and an interactive, electronic suturing board. These models provide feedback, which is so important to integrative level development. "Students using either model are challenged to perform at their best, since immediate feedback and objective skill scores are obtained. Because the exercises are challenging, the students' interest is maintained, resulting in longer attention span and increased practice time" (403). These may be the models that bridge the gap between acquiring basic surgical skills and performing surgical procedures on live aptients. Inanimate models provide predictable response to performance. They are already being used to assess entry level abilities and skill development during the training of veterinary students.

Dennis Olsen and others (1996) performed a study comparing the acquisition of basic motor skills using these next-generation NRPMs with that of training on live animals. Using both subjective and objective evaluation criteria, no significant difference in basic motor skill demonstration was noted between the two study groups. The results of this study indicate that basic psychomotor skills may be better developed using advanced, interactive NRPMs, such as the fluid hemostasis model or the electronic suturing board, than are developed using animals. This is a reasonable conclusion since these models allow unlimited student access, distributed practice, an appropriate integrative level learning environment, and immediate feedback.

Another next generation NRPM is the CathSim by HT Medical Systems, Incorporated (HT 1998a). HT Medical is a leader in virtual reality training technology that has done research and development on virtual reality surgical simulators for the Department of Defense. The CathSim is not a true VR system, but rather a NRPM for venipuncture training that is linked to a personal computer in order to record procedure performance and provide feedback. It can be used as a training or testing model. NRPMs such as these have tremendous potential to improve trauma training in the near future.

Anthropanalogous Models (AAM)

Anthropanalogous models are differentiated from NRPMs by their characteristic of accurate anatomic representation. Many of the materials used to construct AAMs are the same as those used in the construction of NRPMs. AAMs are especially well suited for training paramedic level, minimally invasive resuscitative skills. They aid students in landmark identification and the rehearsal of treatment algorithms. As such, models for training cardiopulmonary resuscitation (chest compression and mouth-to-mouth ventilation), orotracheal intubation, suturing, and peripheral venous catheterization are common. Their universal use in programs such as Advanced Cardiac Life Support (ACLS) accounts for their extensive commercial production (table 4).

TABLE 4
COMMERCIAL TRAUMA TRAINING MODELS

Venous Catheterization	Vendor	Citation	Cost
Lifeform Central Venous Cannulation Simulator	Nasco		
Leardal IV Foot (090022) (AMI: AA-3745)	Laerdal	(Laerdal n.d.; and AMI n.d.)	$310
Laerdal IV Torso (090019) (AMI: AA-3700)	Laerdal	(Laerdal n.d.; and AMI n.d.)	$1,250
Laerdal IV Arm & Hand (090021) (AMI: AA-3740)	Laerdal	(Laerdal n.d.; and AMI n.d.)	$395
Laerdal Basic ALS Trainer Manikin/Heartsim 2000	Laerdal	(Laerdal n.d.)	
Laerdal ALS Skilltrainer 200 Manikin/Heartsim 200	Laerdal	(Laerdal n.d.)	
Leardal IV Hand (AMI: AA-3735)	Laerdal	(Laerdal n.d.; and AMI n.d.)	$210
IV Arm (IVR-3200) Kit (TK-1000)	MPL	(MPL n.d.)	$352
Arterial Stick Arm (AS-1000)	MPL	(MPL n.d.)	$352
Multi-Venous IV Training Arm Kit (IVR-5000)	MPL	(MPL n.d.)	$446
Multi-Venous IV Training Arm - Alone (IVR-5000)	MPL	(MPL n.d.)	$341
Pediatric Itraosseous Leg (NS-8000)	MPL	(MPL n.d.)	$89
Mega-Code ACLS Trainer "Delux Plus" (CPR-4050)	MPL	(MPL n.d.)	$6,500
Advanced I.V. Hand (AB-955)	Armstrong	(AMI n.d.)	$185
Chester Chest (AA-9800)	Armstrong	(AMI n.d.)	$595
Advanced Inj Arm (AB- 950 or 951)	Armstrong	(AMI n.d.)	$495
Inj Arm Trainer (AA-8900)	Armstrong	(AMI n.d.)	$395
IV Training arm (AB-1000)	Armstrong	(AMI n.d.)	$365
Arterial Puncture Arm (AB-1005)	Armstrong	(AMI n.d.)	$345
IV Training Arm & Hand (AA-4340)	Armstrong	(AMI n.d.)	$270
Advacned 4 Vein Ventpuncture Aarm Pad (AA-9675)	Armstrong	(AMI n.d.)	$172
Ambu IV Trainer	Ambu USA	(Ambu USA n.d.)	$500
Adult Arterial And Venous Arm	Gaumard	(Gaumard n.d.)	$585
Adult Training Arm	Gaumard	(Gaumard n.d.)	$230
Advanced Adult Training Arm	Gaumard	(Gaumard n.d.)	$275

Patient Assessment / Stabilization	Vendor	Citation	Cost
ALS Skillmaster Manikin/HeartSim 4000	Laerdal	(Laerdal n.d.)	
Laerdal ALS Skilltrainer 200 Manikin/Heartsim 200	Laerdal	(Laerdal n.d.)	
Complete Care Doll (GDW-2600)	MPL	(MPL n.d.)	$4,615
Mega-Code ACLS Trainer "Delux Plus" (CPR-4050)	MPL	(MPL n.d.)	$6,500

TABLE 4 (CONTINUED)

Chest Decompression	Vendor	Citation	Cost
Mega-Code ACLS Trainer "Delux Plus" (CPR-4050)	MPL	(MPL n.d.)	$6,500
Venous Cutdown	Vendor	Citation	Cost
Laerdal IV Foot (090022)	Laerdal	(Laerdal n.d.)	
Cricothyrotomy	Vendor	Citation	Cost
Mega-Code ACLS Trainer "Delux Plus" (CPR-4050)	MPL	(MPL n.d.)	$6,500
Difficult Airway Management Trainer (AA-3600)	Armstrong	(AMI n.d.)	$1,320
Cricothyrotomy simulator (AB-1140)	Armstrong	(AMI n.d.)	$465
Cricoid Stick Simulator (AA-9450)	Armstrong	(AMI n.d.)	$360
Delux Cric Trainer (AA-9400)	Armstrong	(AMI n.d.)	$200
Basic Cric Trainer (AA-9425)	Armstrong	(AMI n.d.)	$100
Wound Management	Vendor	Citation	Cost
Skilltray	Simutech	(Thomas et al. 1996)	
Suture Board	Ethicon	(Ethicon 2000)	
VaraDerm	Vara Inc	(Lewis and Nusbaum 1987)	
Leg: casting, bandaging (1519) (no bones)	Sawbones	(PRL n.d.)	$100
Leg: casting, bandaging (1515-7)	Sawbones	(PRL n.d.)	$350
Leg: casting, bandaging (1515-9) (no bones)	Sawbones	(PRL n.d.)	$185
Arm: casting, bandaging	Sawbones	(PRL n.d.)	
Complete Care Doll (GDW-2600)	MPL	(MPL n.d.)	$4,615
First-Aid/CPR Manikin (CLS-1000)	MPL	(MPL n.d.)	$1,103
Terry Trauma Manikin (AA-7200)	Armstrong	(AMI n.d.)	$1,050
Nasco Life Form (F1036UA)	Nasco	(Owen et al. 1987)	
Adult Arterial And Venous Arm	Gaumard	(Gaumard n.d.)	$585
Intubation	Vendor	Citation	Cost
Armstrong Adult Intubation Model (AA-3000)	Armstrong	(PCRM 1997)	
Laerdal Airway Management Trainer (AMI: AA-3100)	Laerdal	(PCRM 1997; Laerdal n.d.; AMI n.d.)	$1,325
Laerdal Infant Intubation Model (080001)	Laerdal	(Laerdal n.d.)	
Laerdal Basic ALS Trainer Manikin/Heartsim 2000	Laerdal	(Laerdal n.d.)	
Laerdal ALS Skilltrainer 200 Manikin/Heartsim 200	Laerdal	(Laerdal n.d.)	
ALS Skillmaster Manikin/HeartSim 4000	Laerdal	(Laerdal n.d.)	
Mega-Code ACLS Trainer "Delux Plus" (CPR-4050)	MPL	(MPL n.d.)	$6,500
Difficult Airway Management Trainer (AA-3600)	Armstrong	(AMI n.d.)	$1,320
Armstrong Adult Intubation Trainer (AA-3300)	Armstrong	(AMI n.d.)	$1,360
Ambu Intubation Trainer	Ambu USA	(Ambu USA n.d.)	$1,289
Pericardiocentesis	none found		
Hemostasis	none found		
Peritoneal Lavage	none found		

Note: Price figures are current cost in United States dollars.

In contrast to their extensive use in paramedic programs, few AAMs are available for surgical or invasive resuscitative procedure training. Surgeons have designed abdominal models to include synthetic parenchymal organs for use in veterinary (Holmberg et al. 1993; Greenfield

et al. 1993; Bauer 1993; Holmberg and Cockshutt 1994; Greenfield et al. 1995; and Anastakis et al. 1999) and human surgical training (Lossing and Groetzsch 1992). To date, the use of these models has been limited to instructional research. As noted previously, many models are available for training minimally invasive skills critical to the combat medic; however, AAMs that allow advanced skill training are limited. Patient assessment is limited to models designed for ACLS scenarios simulating a cardiac emergency, or to classification of moulage wounds placed on the mannequin (Maroon and Gosling 1973; and MPL n.d.). Lack of appropriate feedback limits the ability of AAMs to be used as assessment and stabilization models. Only one model allows surgical airway training (AMI n.d.) or chest tube placement (Anastakis et al. 1999). Only one model is designed for venous cutdown training (Laerdal n.d.), but the Sawbones surgical ankle approach model can also be used for this purpose (PRL n.d.). Realistic synthetic bones are available for surgical fracture stabilization training (Neimkin et al. 1983; DeYoung and Richardson 1987; Anastakis et al. 1999; and PRL n.d.) and some commercial mannequins have "broken leg" options for stabilization training (MPL n.d.; and PRL n.d.). Aside from their anatomic fidelity, these AAMs offer few training advantages over significantly cheaper NRPMs and are used to attain similar levels of proficiency. AAM use in training is summarized in table 5.

Studies have been conducted to assess the ability of paramedics to perform unassisted intubation in actual emergencies after stand-alone intubation mannequin training; however, the results of these studies are inconclusive. T. Hilary Howells and others (1973) reported that not one of their AAM trained students achieved first-time live intubation success. Similarly, Ronald D. Stewart and others (1984) determined that AAM training alone was inadequate preparation for first time emergency intubation; however, well supervised paramedics quickly attained proficiency after several intubation attempts. They found that practice on live animals or anesthesia patients increased initial success rates; however, long term success and complication rates were independent of the training method used. A possible reason for initial failure was the

lack of anatomic and haptic fidelity between the mannequin head and the live patient. C.L. Owen and others (1987) support this suggestion that haptic properties of AAMs need improvement in a study comparing epidural catheterization of a mannequin with that of an anesthetized pig. The live pig model was found superior because of the presence of necessary haptic realism.
Studies by Cathy Greenfield and others (1995) support the conclusion that while AAMs may not prepare students as well as animals for initial terminal performance, long term performance is independent of the training model used. These authors conclude that using AAMs for training simple, isolated procedures is comparable to training conducted on live animals except for a notable hesitancy experienced during the student's first live performance of the task. Future, performance success was independent of training modality.

Samuel J. Stratton and others (1991) contradict these findings about unpredictable first time performance, suggesting that paramedic intubation success and complication rates were independent of training modality, even in initial emergency attempts. They note that they used different study criteria than Stewart and that their study failed to achieve significance due to small group size. Despite contradictory results, these studies support the use of AAMs in medic training, and reinforce the suggestion that medics are capable of performing procedures once considered beyond their scope of practice (Mattsson et al. 1980).

TABLE 5
ANTHROPANALOGOUS MODELS USED IN TRAINING

Model	Use	Citation
Commercial Mannequin	Inbtubation Training	(Howells et al. 1973)
Commercial Mannequin	Head Trauma Assessement	(Maroon and Gosling 1973)
Commercial Mannequin	Inbtubation Training	(Nathason et a. 1973)
Foam Bones	Surgical Training	(Neimkin et al. 1983)
Commercial Mannequin	Inbtubation Training	(Stewart et al. 1984)
Synthetic Models	Veterinary Surgical Training	(Jennings 1986)
Commercial Mannequins	Resuscitative Procedures Training	(Klausner et al. 1987)
Commercial Mannequin	Epidural Training	(Owen et al. 1987)
Foam Bones	Veterinary Surgical Training	(DeYoung and Richardson 1987)
Commercial Mannequin	Inbtubation Training	(Nelson 1989)
Commercial Mannequin	Inbtubation Training	(Forbes et al. 1989)
Dental Model	Wound Management and Suturing	(Meyer et al. 1989)
Commercial Mannequins	Resuscitative Procedures Training	(Nelson 1990)
Foam Bones	Veterinary Surgical Training	(Johnson et al. 1990)
Commercial Mannequin	Inbtubation Training	(Stratton et al. 1991)
Foam Models	Technical Skills Program	(Lossing, Hatswell, et al. 1992)
Commercial Mannequin	Procedures Workshop	(Powers and Draeger 1992)
Commercial Mannequins	Resuscitative Procedures Training	(Hill 1993)
Abdominal Organs Models	Veterinary Surgical Training	(Greenfield et al. 1993)
DAISE	Veterinary Surgical Training	(Holmberg et al. 1993)
Veterinary Models	Veterinary Surgical Training	(Bauer 1993)
DAISE	Veterinary Surgical Training	(Holmberg and Cockshutt 1994)
Veterinary Models	Veterinary Surgical Training	(Greenfield et al. 1994)
Sawbones	Orthopedic Training	(Greenfield et al. 1994)
Commercial Mannequin	Inbtubation Training	(Van Stralen et al. 1995)
Veterinary Models	Veterinary Surgical Training	(Greenfield et al. 1995)
Commercial Models	Resuscitative Procedures Training	(PCRM 1997)
Commercial Mannequins	Inbtubation Training	(Wik et al. 1997)
DAISE & Synthetic Bones	Surgical Training	(Anastakis et al. 1999)
Commercial Models	Resuscitative Procedures Training	(PCRM n.d.a)
Sawbones	Orthopedic Training	(PRL n.d.)
Sawbones Ankle Model	Venous Cutdown Training	(PRL n.d.)
Commercial Mannequins	Armstrong Medical	(AMI n.d.)
Commercial Mannequins	Resuscitative Procedures Training	(Laerdal n.d.)
Commercial Models	Venipunture Training	(MPL n.d.)
Commercial Mannequins	Wound Care raining	(MPL n.d.)
Commercial Models	Resuscitative Procedures Training	(AMI n.d.)
Commercial Models	Inbtubation and Venipunture Training	(Ambu USA n.d.)
Commercial Models	Venipunture Training	(Gaumard n.d.)
Appendectomy Model	Surgical Skills Testing	(Lossing and Groetzsch 1992)

Cadavers (CAD)

Descriptions of the use of human and animal cadavers in trauma training has already been discussed (Weaver et al. 1986; Eaton et al. 1990; Nelson 1990; and PCRM 1997). Cadavers have been used extensively in surgical and resuscitative procedure training. Descriptions of the use of animal cadavers or tissues in wound closure training is especially common to include pig (Straith et al. 1961; Oneal et al. 1967; Graham 1974; Snell 1978; Romm and Berggren 1980; Stotter et al. 1986; Wolfe et al. 1988; Anders et al. 1989; Hoffman et al. 1990; Gormley 1990; and Capperauld

and Hargraves 1991) and poultry tissues (Lawrence and Wiviott 1978; and Greenfield et al. 1994). The use of human cadavers is most frequently described for intubation training (Iserson 1986, 1991; Orlowski 1988, 1989; Nelson 1990; Stern and Spitzer 1991; Stratton et al. 1991; and Benfield et al. 1991). In total, cadaver use descriptions include use in veterinary and human surgical training, intubation and surgical airway training, chest decompression, venous access, and orthopedic training. Table 6 summarizes the use of cadavers in training.

The social pressures surrounding the use of human cadavers, especially recently deceased bodies, rival the debate over animal use in training. Extensive philosophical arguments and ethical debates over the use of the recently deceased and family consent issues abound (Nelson 1990; Iserson 1986, 1991; Culver 1986; Feinberg 1985; Kass 1985; Orlowski 1988, 1989; Stryker 1989; Matz 1989; and Morhaim and Heller 1989). The use of human cadavers for trauma training is illegal in England and Norway (Eaton et al. 1990; Brattebo et al. 1994) and limited by availability, religious practice, or legislation within the United States (Culver 1986; Klofas 1997; and Benfield et al. 1991).

Only one study has been conducted with the specific intention of evaluating the use of cadavers as a surgical training model. Larry G. Carpenter and others (1991) compared the use of live dogs and dog cadavers in developing ligation and suturing skills. They found that the model used had no significant impact on student success. They note that this study suffers from a group size too small to significantly support either training model. Additionally, comparisons of animal versus cadaver-model training value might be more appropriately assessed with advanced skills such as delicate tissue handling. More significant than these findings was Weaver's (1986) observation during the conduct of resuscitative procedure laboratories that cadaver availability encouraged his students to practice before actual patient encounters. Many authors indicated that model accessibility (NRPM, AAM, and CAD) encourages practice and the development of psychomotor skills.

TABLE 6
CADAVER MODELS USED IN TRAINING

Model	Use	Citation
Pig Feet	Wound Closure Training	(Straith et al. 1961)
Pig Feet	Wound Closure Training	(Oneal et al. 1967)
CAD Blabber	Surgical Training	(Narwani and Reid 1969)
Pig Feet	Wound Closure Training	(Graham 1974)
CAD Bones	Orthopedic Workshop	(Lippert et al. 1975)
Pig Feet	Wound Closure Training	(Snell 1978)
Turkey Skin	Wound Closure Training	(Lawrence and Wiviott 1978)
Pig Ear	Wound Closure Training	(Romm and Berggren 1980)
Pig Tissues	Anastamosis Workshop	(Bevan 1981)
Animal CAD	Veterinary Surgical Training	(Jennings 1986)
CAD & NRPM	Craft Workshops	(Bevan 1986)
Cat CAD	Tracheotomy Training	(McLaughlin and Iserson 1986)
Human CAD	Medical Procedures Lab	(Weaver et al. 1986)
Human CAD	Intubation & Venipuncture Training	(Iserson 1986)
Pig Tissues	Surgical Training	(Stotter et al. 1986)
Human CAD	Venous Access Training	(Reid and Vestrup 1988)
Human CAD	Intubation Training	(Orlowski 1988)
Pig Tissues	Surgical Training	(Wolfe et al. 1988)
Human CAD	Wound Closure Training	(Anders et al. 1989)
Pig Feet	Wound Closure Training	(Anders et al. 1989)
Human CAD	Resuscitative Procedures Lab	(Nelson 1990)
Human CAD	Surgical Training	(Gormley 1990)
Pig Tissues	Surgical Training	(Hoffman et al. 1990)
Pig Tissues	Surgical Training	(Coroneo 1990)
Sheep CAD	Resuscitative Procedures Lab	(Eaton et al. 1990)
Dog CAD	Veterinary Surgical Training	(Carpenter et al. 1991)
Human CAD	Resuscitative Procedures Lab	(Iserson 1991)
Human CAD	Intubation Training	(Stern and Spitzer 1991)
Human CAD	Intubation Training	(Stratton et al. 1991)
Human CAD	Intubation Training	(Benfield et al. 1991)
Pig Skin	Wound Closure Training	(Capperauld and Hargraves 1991)
Animal CAD	Veterinary Surgical Training	(Bauer, Glickman, Glickman, et al. 1992)
Human CAD	Procedures Workshop	(Powers and Draeger 1992)
Pig Legs	Surgical Training	(Steffens et al. 1992)
Pig Tissues	Surgical Training	(Majeed et al. 1992)
Animal CAD	Veterinary Surgical Training	(Bauer 1993)
Human CAD	Cricothyroid Training	(Johnson et al. 1993)
Animal CAD	Veterinary Surgical Training	(Greenfield et al. 1994)
Chicken CAD	Wound Closure Training	(Greenfield et al. 1994)
Animal CAD	Veterinary Surgical Training	(Pavletic et al. 1994)
Human CAD	Resuscitative Procedures Lab	(PCRM 1997)
Human CAD	Intubation Training	(Wik et al. 1997)
Pig Tissues	Surgical Training	(Van Vreeswijk and Pameyer 1998)
Human CAD	Surgical Training	(Anastakis et al. 1999)
Porcine Thorax	Thoracotomy Training	(Anastakis et al. 1999)
Human CAD	Resuscitative Procedures Lab	(PCRM n.d.a)

Complex Interactive Mannequins (CIM)

No article specifically addresses the use of complex interactive mannequins in trauma or surgical training. CIMs are used primarily in anesthetist training, but are being increasingly used by other disciplines. Stephen Abrahamson and others (1969) first discussed the use of complex interactive mannequins in training at the University of Southern California. Another early CIM

was used by the University of Florida at Gainesville, who continues to use their own model (Chopra et al. 1994; UF 1996). More recently, "Using simulators for education and training in anesthesiology" provides an excellent review of complex interactive mannequins. "A full-patient simulator [CIM] consists of a human mannequin animated with a variety of electromechanical or pneumatic devices that produce respiratory movement, palpable pulses, heart and lung sounds, realistic airway anatomy, exhaled carbon dioxide, thumb twitches and 'urine.' Complex interactive mathematical models of drug function, metabolism, cardiac function, gas exchange and fluid balance are resident in an integral system computer." Responses to administered medications are registered in patient monitors attached to the mannequin (Murray and Schneider 1997, 1).

CIMs have found their greatest application in anesthesiology training. Their simulations, involving physiologic responses to pharmacological agents as indicated on patient monitors, are well suited to challenging students at the higher levels of cognitive learning. Students must assess and respond to the "patient." CIMs allow the rehearsal and comparison of different treatment protocols. CIMs are especially useful in challenging students with major critical events such as power loss, anaphylaxis, malignant hyperthermia, medication contamination, drug overdose, and fire. Such scenarios can only be trained using simulation. CIMs have also proven realistic enough allow the prospective study of anesthetist critical incident responses (Gaba and DeAnda 1989; and DeAnda and Gaba 1990,1991). Other applications include the use of CIMs for medical team response training, just as the airline industry has long done with VR flight simulators. Investigators are also evaluating the use of CIMs for use in clinical competency testing.

Several manufacturers produce CIMs ranging in capability from computerized AAMs to truly advanced interactive mannequins (table 7). The Medical Education Technologies, Incorporated (METI), Human Patient Simulator (HPS) is the most advanced CIM commercially available today. Unique characteristics of the METI-HPS include air-exchanging, self-regulating

lungs, hand held instructor remote controls, pulmonary catheter output, thermomodulation, automated drug recognition, and a difficult airway module (UW n.d.). The MedSim Advanced Medical Simulations, Limited (MedSim), PatientSim similarly offers many features that might enable trauma training. While these simulators allow the performance of intubation, surgical airways, needle thoracotomy, chest tube insertion, and fracture stabilization, these capabilities are designed to demonstrate the response to intervention rather than to allow realistic procedural performance. Currently neither allows fluid resuscitation, wound management, or venous cutdown (Norman and Wilkins 1996; METI 1997; and MedSim 1999). As trauma training tools, these models suffer from the lack of design features allowing realistic procedural performance; however, trauma pathophysiology computer models, fractures, and sites for invasive interventions are being improved (Good 1997). Both of these CIMs are priced around $200,000.

TABLE 7
COMPLEX INTERACTIVE MANNEQUINS

Model	Vendor	Citation
Human Patient Simulator (CAE)	CAE Electronics Corporation	(Norman and Wilkins 1996)
ALS Skillmaster Manikin/HeartSim 4000	Laerdal Medical Corporation	(Laerdal n.d.)
ALS Skillmaster Manikin/HeartSim 4000	Laerdal Medical Corporation	(Laerdal n.d.)
Leiden Anesthesia Simulator	Leiden University, The Netherlands	(Chopra et al. 1994; and UW n.d.)
Gainsville Anesthesia Simulator	Loral Corporation	(UF 1996; and Norman and Wilkins 1996)
Human Patient Simulator (METI)	Medical Education Technologies, Inc.	(METI 1997 and Mount Sinai n.d.; UW n.d.)
Complete Care Doll (GDW-2600)	Medical Plastics Laboratory, Inc	(MPL n.d.)
Mega-Code ACLS Trainer "Delux Plus"	Medical Plastics Laboratory, Inc	(MPL n.d.; and Funk 2000b)
Complete Care Doll (GDW-2600)	Medical Plastics Laboratory, Inc	(MPL n.d.)
Human Patient Simulator	MedSim Advanced Medical Simulations, Ltd.	(MedSim 1999)
PatientSim	MedSim Advanced Medical Simulations, Ltd.	(MedSim 1999)
SimOne (Univ Calif)	University of California	(Abrahamson et al. 1969)

Less expensive CIMs are actually computerized AAM mannequins. While these models are designed at allow the performance of intubation, surgical airways, chest decompression, catheterization, wound management, and fracture stabilization, their ACLS based scenarios are designed to provide cardiac emergency intervention feedback (Laerdal n.d.; and MPL n.d.). These models allow for a greater range of invasive intervention, but they are not truly appropriate for

use in training trauma patient assessment and patient stabilization. Instructors are more likely to consider these for use in training invasive resuscitative procedures since they are less expensive to purchase and maintain.

While no CIM is specifically designed for trauma training, the Uniform Services University of Health Sciences (USUHS) and the Joint Special Operations Medical Readiness Training Center (JSOMTC) are using CIMs in military medical training. USUHS is using its HPS for medical student examination and diagnostic procedure training, and the JSOMTC is actively studying the application of CIMs into medic training (Funk 2000a; and USUHS n.d.). Additionally, the U.S. Army's Simulation, Training, and Instrumentation Command has developed the Combat Trauma Patient Simulator (CTPS), including the use of CIMs, in order to enable individual and multi-echelon medical unit training (STRICOM 1998).

Analysis of the Literature

Despite the number of articles reviewed, objective evidence collection was limited. The bulk of the literature on this topic is descriptive in nature; however, some analysis of model characteristics was offered. Evaluations of the teaching efficacy of individual models were rare; comparisons were even rarer. No prospective study offered a comparison of one specific model against another in training procedural competency that was tested on actual emergent patients.[6] In deriving conclusions from such articles, the reader must remain cautious of analytical pitfalls: semi-quantitative analysis is not objective, model evaluations do not allow comparison across developmental levels, and the definition of "realism" has not been agreed upon.

The most common method of comparison used in this area is semi-quantitative analysis. The goal of semi-quantitative analysis is to add a flavor of objectivity to subjective data. A semi-quantitative evaluation is one in which numerical scores are assigned to subjective observations or assessments, so that the scores create data sets appropriate for statistical analysis. It is

important to remember that the data collection process is inherently biased, and while the conclusions may be significant, they are not objective. A different group of evaluators may also make significant conclusions with exactly opposite findings.

Many evaluations offered conclusions based on subjective criteria such as student perceptions or instructor evaluations. Most of these articles conclude that the training method described was beneficial and resulted in increased student proficiency and confidence; however, they suffer from lack of control ("compared to what?" factor). Such studies cannot be used as the basis for objective conclusions about a model category or for comparisons between models. Comparison of two such studies measuring the efficacy of cadaver and animal use in the attainment of student confidence and proficiency illustrates this potential, which is common to many of the articles. M. E. Weaver and others (1986, 409) note that it was the "unanimous impression of all students that the [cadaver lab] experience was valuable and that [afterwards] they felt more qualified and confident." Similarly, Jonathan S. Olshaker and others (1989, 595) report that "using an unpaired *t*-test, the change in comfort levels was significant for all six procedures. . . . (100%) felt the [live] swine procedure laboratory was a valuable experience. . . . (100%) felt the swine laboratory helped or will help them perform these procedures on humans." Individually, each article offers a convincing argument that the discussed model provides training advantages. Cumulatively, these articles suggest only two conclusions: (1) They reinforce Michael S. Bauer, N. Glickman, S. K. Salisbury, and others' (1992) observation that surveyed students tend to support the method to which they have been exposed. (2) They reinforce the age-old adage that some practice is better than no practice. One must exercise caution when arriving at any other conclusions. Where there is no comparative standard, nor comparison intended by the author, comparisons should not be made.

Several evaluations conclude that the attainment of basic psychomotor skill on one model is as effective as that attained on another stated model (Smeak 1989; Olsen et al. 1996; Smeak et

al. 1991; Carpenter et al. 1991; Greenfield et al. 1995; Anastakis et al. 1999; and Wik et al. 1997). Caution must be exercised in equating the adequacy of a model in developing basic skills at the integrative level with autonomous level development or the preparation of the student for terminal performance. Most authors concede that additional training is required before terminal performance. Provision of emergency care to the critically injured patient requires the application of advanced technical skills, knowledge, and appropriate problem-solving ability in a stress-laden environment. T. Hillary Howells and others (1973) found it nearly impossible to construct a useful system of scoring for the comparative evaluation of training models. The crucial question that must be answered is: Did this exercise prepare the students for the next level of training or for terminal task performance? This question is answered by evaluating future performances, not by evaluating performance during training.

Finally, caution must be exercised in noting the context in which the author describes a model's characteristic of realism. "Realism" is used at least three different ways: anatomic realism, haptic realism, and clinical realism. Anatomic realism implies that the model is an anatomically correct representation of the human body. Haptic realism implies realistic touch sensation or tissue feel as compared to living human tissues. Clinical realism is a broader term encompassing aspects of environmental appropriateness, procedural difficulty, problem solving, and complications. Responses to intervention and complications can be procedural (bleeding) or patient-based (individual anatomic variation or physiological response). Distractions, poor visualization due to secretions or blood, dynamic systems, laryngospasm or swallow reflex during intubation are all examples of increased clinical realism. The reader must ensure that the realism of a model is noted in terms of the context in which the term is used.

Studies comparing the use of animate and inanimate models in training are available; however, the evidence presented to support the use of one model over another is generally inconclusive due to subjective criteria or statistical insignificance. Generally, these studies offer

small group sizes, so that trends may be reported, but significant conclusions cannot be made. Additionally, readers must be cautious of analytical pitfalls that are present in the literature concerning this topic. Nevertheless, these articles do provide evidence that can be used in determining the appropriate training niche for the evaluated models and the ability of inanimate models to replace the use of animals in trauma training.

Summary

This literature search was conducted to gain evidence on the topics of animate and inanimate model use in trauma training. Out of nearly five hundred manuscripts reviewed, only fourteen directly dealt with model use during the conduct of resuscitative procedure laboratories such as the ATLS practicum. Other articles pertinent to the subject of model use in training were reviewed to gain additional evidence to aid in the characterization of the identified models and determine the ability of these models to replace the use of animals in trauma training. The principles of procedural psychomotor development were reviewed as a basis for determining the appropriate role of the described models in trauma training. Despite the fact that most articles were descriptive, and the fact that most of the studies reviewed suffered from subjectivity and statistically insignificant conclusions, analysis of these papers assists in the characterization of the varied models. The literature review provided adequate material to satisfy the evidentiary requirements of the selected methodology.

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1. MEDLINE (154), AGRICOLA (10), BIOSIS REVIEWS (55), EMBASE (73), PASCAL (144), SCISEARCH (434), INSPEC (2), NTIS (6), EI COMPENDEX (8), IAC COMPUTER DATABASE (275), MICROCOMPUTER ABSTRACTS (233), MICROCOMPUTER SOFTWARE GUIDE (278), AGRIS (203), CAB ABSTRACTS (50), ERIC (1), A-V ONLINE (46), LIFE SCIENCES (76), FEDRIP (266), TRIS (63), ZOOLOGICAL RECORD (185). Numbers in parentheses are DIALOG database codes.

2. See ACS, Adam, Ali, Anderson, Aprahamian, Ariyanayagam, Ben-Abraham, Bennett, Berridge, Blumenfeld, Collicott, Crerar-Gilbert, Deane, Dodds, Eaton, Esposito, Finfer, Gautam, Girdley, Greenslade, Griffiths, Gwinn, Gwinnutt, Hal, Han, Hughes, Kilkenny, Lavery, Leigh, Mehne, Messick, O'Higgins, Ornato, Pons, Poulton, Roy, Salander, Sims, Thompson, Tortella, Vestrup, Walsh, Wiedeman, Williams, and Worlock.

3. See Baker, Bellamy, Ben-Abraham, Blumenfeld, Bolton, Cahill, Ekblad, Heydorn, Kluger, Knudsen, Lisitsyn, Mattsson, Parisi, Smith, Tangney, Walsh, Wiedeman, and Zajtchuk.

4. The most familiar example of overlearning is riding a bike--you never forget how to ride a bike (Chapman 1994).

5. Benjamin S. Bloom's (1956) taxonomy of cognitive learning (knowledge, comprehension, application, analysis, synthesis, and evaluation) should not be confused with the cognitive level of procedural psychomotor development.

6. The only true measure of model efficacy--the Gold Standard--is to evaluate student performance on actual emergent patients after the training event.

CHAPTER 3

RESEARCH METHODOLOGY

Research Design

The purpose of this study is to explore alternatives to live animal use in support of military medical trauma training. The primary research question is: Can nonanimal alternatives replace the use of live animals in military medical trauma training? The supporting questions are: What is the value of using live animals in trauma training? and What nonanimal alternatives are available for use in trauma training? Collection of evidence to answer these questions took the form of a literature search. As part of the literature review, sources were evaluated for merit and credibility. Surveys or interviews of educators and students were specifically excluded from evidence collection due to anticipated bias. The evaluation of the data collected from the literature used a content analysis and comparative approach.

First, models were evaluated using niche analysis. Individual alternatives were evaluated for training value and availability, then grouped by type. Alternative categories were evaluated for characteristics that might positively or negatively influence trauma training. Similarly, the use of animals in training was evaluated to derive its benefits and disadvantages. Comparison of the advantages and disadvantages of the different training models, in light of the principles of psychomotor skill development, demonstrates their most appropriate use at different levels of trauma training--their niche. Additionally, an Event-Totality Standard (ETS) was applied to the described alternatives to determine if the use of multiple models could replace the use of animals in the trauma-training laboratory. A list of critical resuscitative procedures was used as the replacement criterion for the ETS. If the niche which animals fill in trauma training is not unique, if inanimate models can fill it, then the use of animals in trauma training can be replaced. Similarly, if inanimate models can, individually or collectively, satisfy the ETS without the loss of training value to the student, then animal use in trauma training can be replaced. Together,

niche analysis and the Event-Totality Standard answer the primary question: Can nonanimal alternatives replace the use of live animals in military medical trauma training? Figure 1 presents a graphical representation of this methodology.

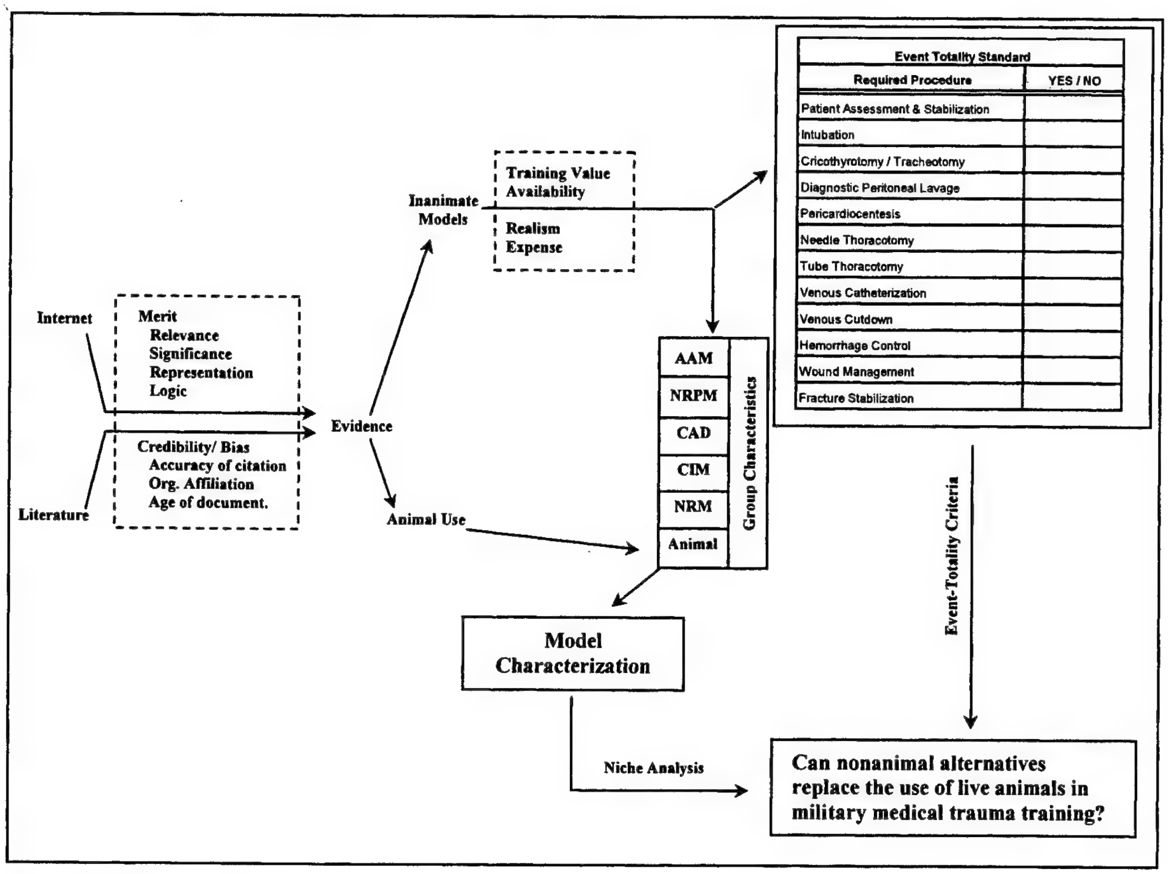

Figure 1. Research Methodology.

Evidence Collection

Evidence was collected to gain data supporting the secondary questions regarding the availability of nonanimal alternatives and the value of live animal use in training. Chapter 2 contains a detailed discussion of the literature search results. Most of the relevant literature was found in professional medical journals. Relevant books, periodicals, and Internet offerings were also reviewed. Full-text articles were retrieved for analysis and bibliographic scrub to identify additional sources. Pertinent manuscripts were evaluated for merit and credibility, then analyzed

to extract evidence for this study. Nearly five hundred manuscripts were evaluated during the data collection process.

Evaluation of the articles included not only a search for evidence to answer the thesis questions, but it also involved an evaluation of each article's merit and credibility. Academic merit was evaluated based on relevance, significance, representation, and logic. Articles that lacked relevance to the use of animate or inanimate models in medical training were eliminated. Such articles were rare and usually pertained to the use of models (AAMs) in the evaluation of new medical devices or techniques. Significance is a function of the methodology, the selection of study groups, and the size of the data set used to arrive at the study's conclusions. Larger study groups produce larger data sets and lend to significant (repeatable) conclusions rather than trends. Similarly, representation is a function of the selection of study groups to adequately represent the population at large. This study assumes that the training of veterinary or medical students in basic surgical skills is representative of the psychomotor skill development required of medics learning basic resuscitative skills. However, the application of conclusions drawn from the training of experienced surgeons in new techniques towards the initial training of medics in trauma skills would not be representative. The psychomotor abilities and experience level of these two groups varies considerably. Finally, the articles were evaluated for logically derived conclusions based on the evidence presented.

The topic of animal use in training is controversial and may lend to bias, voluntary or involuntary, on the part of authors. The credibility of individual articles was evaluated based on the author's accuracy in reporting conclusions from cited works and evidence of affiliation of the author with anti-vivisectionist groups, as well as the previously mentioned aspects of general academic merit. The date of publication was also factored into the consideration of credibility since alternative technologies and attitudes about alternative use have changed substantially over the past few decades. For example, James McLaughlin and Kenneth V. Iserson (1986) mention

the benefit of acquiring cats for tracheotomy practice from animal control shelters. The use of shelters as an experimental animal source is generally considered unacceptable today. As such, these remarks should also be discounted as being outdated; however, credibility issues are not mentioned in this review unless the article was suspect of bias.

Interviews and surveys were not conducted as part of the evidence collection process. The use of one training model versus another demonstrates a preference on the part of the course director, and likewise, a student's participation in a given event demonstrates partiality. The evaluations offered by these groups can be expected to be biased, voluntarily or involuntarily, and do not pass the evidentiary criteria of credibility. In a study examining training model effects on student attitudes, perceptions, and learning experiences, Michael S. Bauer, N. Glickman, S. K. Salisbury, and others (1992, 57) stated that the validity of questionnaires remains controversial despite studies supporting their accuracy. Each student group believed that they had a good learning experience and answered questions in support of their specific training model. The authors concluded that in their study "students supported the method to which they were exposed." This does not rule-out the validity of surveys as a measure of student perceptions or instructor opinion; it does, however, rule-out their use as a comparative tool between models or methodologies. Hence, without expectation of unbiased answers, surveys and interviews were excluded from this study, and evidence collection relied on published material.

Data Evaluation

Described alternatives were evaluated individually, as an alternative group, and collectively. Individual alternative descriptions were evaluated for availability and characteristics of training value. Training value is a function of the model's ability to facilitate the attainment of the training objective for a laboratory. While model characteristics, which determine a model's appropriateness at a given psychomotor development level, do not vary, the model's

appropriateness for a given training exercise may vary according to the event's training objectives. Skill development, certification, or retention may comprise different training objectives at different levels of training. The development of differing degrees of technical proficiency and confidence by different operator populations may also be desired or required. While realism is an important criterion, very basic skills may be better learned through the repetitious use of less realistic models. Hence, the training value of a model is dependent on the psychomotor skill of the student, the level of training desired, and the specific skills to be developed, tested, or maintained. Availability was assessed as a function of commercial production and relative expense of the model. The fact that homemade models are not as readily available as commercially available ones may detract from their use in training. Although alternative cost should theoretically not be a factor in the decision to use alternatives in place of animals, or vice versa, practically it is. Hence, alternative costs at the time of publication are offered when available.

Alternatives were categorized by group (NRPM, AAM, CAD, and CIM), and analyzed using niche analysis. The groups were evaluated for characteristics which offered benefits to their use in trauma training or detracted from the event. Each groups' characteristics, along with those of animal models, were analyzed to determine their advantages or disadvantages during different levels of trauma training. The level of psychomotor development at which a model is most appropriately used in training determines its niche. While at one performance level procedures may be adequately trained on a variety of models, learning at other levels may require specific elements, such as repetition or realism, to achieve the training objective. An evaluation of the characteristics of the different model groups, in light of the training objectives of different events, allows the determination of the optimal model for each event.

Similarly, evidence related to the use of animal models was evaluated to determine the importance of their use in training. As a group, animal models were analyzed to determine their

advantages or disadvantages during different levels of psychomotor development. This assessment was identical to the group characterization of inanimate models. In essence, animals were considered a separate model group and analyzed to determine their own niche in trauma training. If inanimate models equally share this niche, then the animal model can be replaced. This analysis partially answers the primary question by establishing the most appropriate role of each model group in trauma training.

Next, the ability of inanimate models to replace animals in trauma training was analyzed using an Event-Totality Standard. As discussed in chapter 1, trauma training is a terminal event for the animals involved. The goal of the alternative search is to find a training method in which alternatives will, individually or collectively, replace animal use in the training event. Alternatives which replace the need to perform individual procedures on the animal, but which do not replace all of the procedures, do not replace the need to use the animal. The ETS demands that either the animal use be replaced entirely, or not at all. Described inanimate alternatives were evaluated according to their collective ability to replace the animal facilitated trauma-training event. A set of commonly performed resuscitative procedures was selected to comprise the Event-Totality Standard for the elimination of animal use in trauma training (table 8) (Monaghan 1973; Mattsson et al. 1980; STEM 1985, Blumenfeld et al. 1997; Olshaker et al. 1989; Ekblad 1990; Eaton et al. 1990; Heydorn 1990; Kluger et al. 1991; Baker 1994; and ACS 1997). A trauma skill laboratory using only inanimate models must allow the student to attain the same level of proficiency in each of these critical procedures, as would be obtained by using the animal model, in order to satisfy the ETS for the replacement of animal use in the trauma laboratory.

TABLE 8
EVENT TOTALITY STANDARD--REQUIRED PROCEDURES

Patient Assessment	Chest Decompression
Patient Stabilization	Needle Thoracotomy
Airway Management	Tube Thoracotomy
Intubation	Venous Access
Cricothyrotomy	Catheterization
Tracheotomy	Venous Cutdown
Peritoneal Lavage	Hemorrhage Control
Pericardiocentesis	Wound Management
	Laceration Repair
	Fracture Stabilization

Summary

This study was designed to identify and analyze alternatives to live animal use in trauma training. Animate and inanimate models were evaluated to determine their unique benefits and disadvantages in the training of trauma skills. Ultimately, inanimate models can only replace animals in trauma training if they allow the attainment of a comparable level of proficiency for the given student population, level of training, and educational objectives. Niche analysis and an Event-Totality Standard was used to assess whether the suggested alternatives, individually or collectively, might replace the use of animals in trauma training. This analysis yields answers to the questions posed by this thesis.

CHAPTER 4

RESULTS

This thesis used ATLS-like resuscitative procedure laboratories as the basis of evaluation to answer the question: Can nonanimal alternatives replace the use of animals in military medical trauma training? Evidence collection recovered over five hundred discussions of animate and inanimate model use in training. This evidence was analyzed using niche analysis and the Event-Totality Standard to determine the ability of inanimate models to replace animals in the conduct of resuscitative procedure laboratories.

First, niche analysis was applied to the different model groups. By determining the most appropriate role for each model type in trauma training, its niche, the value of that model to the overall training objective of producing confident, competent trauma responders is established. Inanimate models were categorized (NPM, NRPM, AAM, CAD, and CIM), then analyzed to determine characteristics that provide training advantages or detract from training. Comparison of these model characteristics with the principles of procedural psychomotor development allows models to be assigned an appropriate niche in trauma training. Animal models were similarly analyzed to determine their niche. Determining the psychomotor development niche for each model not only establishes the value of animals in trauma training, but also determines the value of the other model categories as well. Clearly, if any model or group of models fills the same niche as animals used in trauma training, without the loss of training value, then the animal use can be replaced.

Secondly, an Event-Totality Standard, comprising critical resuscitative procedures, was used to determine the individual or collective ability of the identified models to replace the use of animals in trauma training. The ability of inanimate models to satisfy the ETS would indicate their ability to replace the use of animals in trauma training. On face value, the ETS might appear easily satisfied, since there are obviously inanimate models that should allow the performance of

each of the required procedures. However, the models must allow learning at the student's given level of psychomotor ability comparable to that provided by animals. Thus, niches are an important consideration in applying the Event-Totality Standard. Finally, practical issues such as model availability may preclude the use of some models necessary to fulfill the ETS. Despite the fact that a given set of alternatives might replace the use of animals during a given training event, the course director may not have access to the required models or the logistics of using that set of models may in itself detract from the training event.

The evidence for this analysis was collected from articles that were mostly descriptive. Those articles offering model evaluation suffered from subjectivity and were generally unable to report statistically significant results. The described methodology was selected in order to reduce subjectivity through the deliberate identification, characterization, and analysis of trauma training models. Determining each model's niche in psychomotor training and the collective ability of the identified models to satisfy the Event-Totality Standard answers the question: Can nonanimal alternatives replace the use of animals in military medical trauma training?

Niche Analysis

Niche analysis was performed by comparing identified model group characteristics with the model characteristics derived from psychomotor skill development principles, which are expected to enhance or detract from training at the different levels of development. Table 9 reviews the levels of procedural psychomotor development, the educational goals of each level, and training model characteristics that are beneficial or detrimental to learning at each level of training. Understanding the relationship of model characteristics to educational goals at each level of psychomotor development is essential to defining a model's niche.

At the cognitive level of development, models that increase attention span or interest in the material are beneficial. Interactive nonrealistic models such as IVD/CS are especially

appropriate for this level of development. Models that allow repeated procedure sequence rehearsal also allow these steps to be much more reliably ingrained and increase retention. Models such as VR and NRPMs are ideal for this type of simple manual rehearsal. Other animate or inanimate models could be used at this point, but are not justified at this level of psychomotor development because of expense, complexity, or logistical considerations.

TABLE 9
SKILL DEVELOPMENT LEVELS

Level	Cognitive	Integrative	Autonomous
Educational Goals	Knowledge Base ↑ Performance Steps Indications / Contraindications Instrumentation	Dexterity Basic Skills Dev. Overlearning Hand-Eye Coordination	Competence Independence Confidence Delicate Motor Skill
Models			
Training Benefits	Attention Span ↑ Interactivity Step Rehearsal	Distribute Practice Frequent Access Feedback	Challenge Clinical Realism Haptic Realism
		← Meaningfulness Anatomic Realism →	
Training Detractors	← Stress / Anxiety / Frustration →		

The development of motor skills begins in the integrative phase of psychomotor development. The goal of this level is the development of student dexterity and hand-eye coordination. Dexterity and hand-eye coordination are gained through repeated practice of basic procedures such as knot tying, instrument handling, ligation, suturing, dissection, and incision. Overlearning basic skills through repeated practice after the skill has been mastered increases manual skill retention. Since the goal is the development of the combined cognitive and motor skills necessary to properly perform basic procedures, realism is not as important as repeated practice at this stage of development. Models which encourage frequent practice are more beneficial than more realistic, yet less accessible, models (Greenfield et al. 1995). Increased

student access to training models encourages students to repeatedly practice motor skills and allows frequent, distributed practice sessions. Feedback reinforces correct performance and prevents students from learning error patterns. Model feedback is especially beneficial when students are practicing without the supervision of an instructor (From et al. 1994). Boredom with the repetitious performance of basic skills using simple models occurs. Establishing the clinical relevance of these practice exercises increases student interest and acceptance of less realistic models (Johnson and Farmer 1989). Conditions that increase stress and anxiety lead to student distraction, error patterns, poor performance, and frustration. Performance stress must be avoided at this level of psychomotor development.

The goal of the autonomous level of psychomotor development is to "lock-in" gross motor skills, refine delicate motor skills, and prepare the student for terminal task performance. Since actual resuscitative procedure performance is seventy-five percent cognitive, the goal is to develop the student to a point where manual performance of trauma skills is automatic. At this point his full attention can be focused on continual patient assessment and response to intervention (Spencer 1983). Such performance is achieved in a training environment that very nearly represents the anticipated terminal performance environment (Smeak et al. 1991). Models and training exercises that provide clinical realism to include patient and procedural complications, environmental distractions, and a sense of urgency introduce the student to performing resuscitative tasks in a stressful environment. Challenging training scenarios force the student to use medical decision making skills and improve his confidence. Haptic and anatomic realism allow the refinement of delicate motor skills from the gross motor skills developed during the integrative phase of training. The student who is trained to the autonomous level of development will be capable of competent, confident, independent performance of resuscitative skills.

Models were grouped and analyzed to identify characteristics, which demonstrate their appropriate roles for use in psychomotor skill development. The goal is not to identify the most realistic model, the least expensive one, the most exciting one, or the one that allows the performance of the greatest number of procedures. The goal is the identification of the "appropriate model for the appropriate situation" (Greenfield et al. 1994 ,12). Niche analysis allows the identification of the most appropriate role for each model in trauma training.

Nonrealistic Physical Models (NRPM)

The greatest advantage of nonrealistic physical models is that they are commercially available or simply constructed, and inexpensive. As such, they are readily available to students who are encouraged to practice basic skills frequently. Several authors note the tendency of students to take NRPMs home or practice at school after class; some buy their own models for home use (Smeak 1989; Thomas et al. 1996; Anastakis et al. 1999; and Smeak et al. 1991). Such availability is largely due to their low cost. NRPMs are easily stored and maintained, and they allow for repeated use by several different students. Finally, students feel no stress or urgency when performing procedures on NRPMs, as they might on animals or live human patients.

Nonrealistic physical models suffer from lack of realism, as indicated by their name. This group of models never offers clinical or anatomic realism, but occasionally are designed to offer haptic realism (Anastakis et al. 1999; and Greenfield et al. 1993). Nevertheless, they are inappropriate for development of fine tissue handling skills. Only rarely do these models offer feedback mechanisms, so the habitualization of error patterns is possible without instructor supervision (Bauer and Seim 1992; and HT 1998a). Lack of feedback and realism leads to student disinterest if efforts are not made to demonstrate clinical relevance; however, demonstration of meaningfulness maintains student interest (Bauer and Seim 1992). W. E. G. Thomas and others (1996) found that after exposure to models, students preferred NRPM use prior to progressing to

live animal model training, in order to master basic skills. Table 10 summarizes the characteristics of NRPMs.

TABLE 10
NONREALISTIC MODEL CHARACTERISTICS

Training Benefit	Citation
Inexpensive / Simply Constructed	(Smeak 1989; Southern and Browning 1995; Thomas et al. 1996; Klofas 1997; Johnson and Farmer 1989; and Anastakis et al. 1999)
Student Availability	(Eggerston 1983; Lewis and Nusbaum 1987; Smeak 1989; Klofas 1997; Greenfield et al. 1994; Anastakis et al. 1999; Smeak, et al. 1991; Thomas et al. 1996; and Anastakis et al. 1999)
Allow Repetitive Practice	(Eggerston 1983; Lewis and Nusbaum 1987; Thomas et al. 1996; Klofas 1997; Kopchok et al. 1993; Buyukmihci n.d.a; Greenfield et al. 1994; Johnson and Farmer 1989; Anastakis et al. 1999; and Smeak et al. 1991)
Multiple Use Models	(Sinclair 1984) (Kopchok et al. 1993) (Anastakis et al. 1999)
Easily Stored / Maintained	(Johnson et al. 1990) ; Anastakis et al. 1999)
Anxiety Free Learning	(Sinclair 1984; Smeak 1989; Greenfield et al. 1994; and Smeak et al. 1991)
Training Detractor	Citation
Lack of Realism	(Southern and Browning 1995; Thomas et al. 1996; Anastakis et al. 1999)
Lack of Feedback	(Bauer and Seim 1992)
Loss of Interest	(Bauer and Seim 1992)
Not commercially available	(Smeak 1989; Southern and Browning 1995; and Klofas 1997)

Based on these characteristics, nonrealistic physical models are ideal for use during the integrative phase of psychomotor skill development. The evidence supports NRPMs as potentially being the best model for the development of basic surgical skills such as instrument handling, knot tying, and suturing. Daniel D. Smeak (1989) found that students who had trained on NRPMs alone performed ligation on live animals as well as, and sometimes better than, students who had trained repeatedly on live animals. This finding is attributed to the greater opportunity for practice in the group using NRPMs. Similarly, Ann L. Johnson and James A. Farmer (1989, 12) found that the "use of large and unrealistic models was superior to animals in

the demonstration of basic skills and concepts before moving on to more realistic" training procedures. This evidence supports the conclusion that NRPMs clearly fit into the niche of integrative level training as an excellent model for basic psychomotor skill development.

Anthropanalogous Models (AAM)

The training benefits and detractors associated with AAM use are very similar to those cited for NRPM use, with the exception of anatomic realism and widespread commercial availability. As their name suggests, anthropanalogous models are known for being anatomically accurate models. The use of AAMs for emergency medical training is currently the accepted standard of training for minimally invasive scenarios such as CPR. The commercial availability of these models has already been demonstrated. Like NRPMs, they are easily stored and transported to training sites. They have the same characteristics as NRPMs that encourage frequent repeated practice, such as accessibility, durability, and multiple-student repeated use. Bruce W. Pince (1970) and Marc S. Nelson (1990) note that their standardization is a benefit in allowing for group training and for use in testing. Finally, like NRPMs, these mannequins allow students to practice in a stress free learning environment.

The most common detracting characteristic of AAMs also defines their niche in trauma training. Their lack of clinical realism means that AAMs are inappropriate for use as training devices at the autonomous level of psychomotor development. Mannequins do not bleed, nor do they provide feedback, individual biological variation, or treatment complications. The debate about whether training with AAMs may be adequate preparation for terminal performance of basic emergency skills such as venipuncture and intubation remains inconclusive (Stewart et al. 1984; and Stratton et al. 1991). Lack of haptic and anatomic realism does not allow the refinement of techniques such as delicate tissue handling. Greenfield and others (1993) note the complexity of creating models with haptic fidelity to include the characteristics of friability,

suture holding properties, cutting properties, vascular pattern, exterior texture, palpation, and overall appearance. Greenfield and others (1995) caution against students losing interest while practicing on AAMs; this caution was also noted for NRPMs. Finally, as compared to NRPMs, AAMs are relatively expensive with prices ranging from one hundred dollars to several thousand dollars. Table 11 summarizes the characteristics of AAMs.

TABLE 11
ANTHROPANALOGOUS MODEL CHARACTERISTICS

Training Benefit	Citation
Anatomic Realism	(Pince 1970; Nelson 1990; PCRM n.d.a; Jennings et al. 1974; Powell et al. 1991; Maroon and Gosling 1973; Meyer et al. 1989; and Greenfield et al. 1993)
Commercially Available	(Howells et al. 1973; Maroon and Gosling 1973; Nathason et a. 1973; Stewart et al. 1984; Owen et al. 1987; Nelson 1989, 1990; Forbes et al. 1989; Stratton et al. 1991; Powers and Draeger 1992; Van Stralen et al. 1995; Klausner et al. 1987; Hill 1993; Wik et al. 1997; AMI n.d; Laerdal n.d.; MPL n.d.; PCRM 1997; PCRM n.d.a; MPL n.d.; AMI n.d.; Ambu USA n.d.; and Anastakis et al. 1999)
Standardization	(Pince 1970)
Student Accessibility	(Klausner et al. 1987; Howells et al. 1973; Johnson et al. 1990; Greenfield et al. 1993; Holmberg et al. 1993; Greenfield et al. 1995; Stratton et al. 1991; and Anastakis et al. 1999)
Repeated Practice	(PCRM 1997; Nelson 1990; PCRM n.d.a; Howells et al. 1973; Johnson et al. 1990; Greenfield et al. 1993; Holmberg and Cockshutt 1994; Buyukmihci n.d.a; Greenfield et al. 1995; and Anastakis et al. 1999)
Durability & Repeated Use	(Howells et al. 1973; Johnson et al. 1990; Greenfield et al. 1993; Holmberg and Cockshutt 1994; Buyukmihci n.d.a; and Anastakis et al. 1999)
Storage Ease & Portability	(Johnson et al. 1990; and Anastakis et al. 1999)
Confidence in Basic Skills	(Howells et al. 1973; Holmberg and Cockshutt 1994; and Stratton et al. 1991)
Anxiety Free Learning	(Greenfield et al. 1993; Holmberg et al. 1993; and Holmberg and Cockshutt 1994)

TABLE 11 (CONTINUED)

Training Detractor	Citation
Relative Expense	(Nelson 1990; Eaton et al. 1990; Jennings 1986; AMI n.d; Laerdal n.d.; MPL n.d.; PCRM 1997, n.d.a; AMI n.d.; and Ambu USA n.d.)
Procedures Limited	(Eaton et al. 1990)
Model Maintenance	(Nelson 1990)
Lack of Clinical Realism	
Lack of Feedback	(Calderwood and Ravin 1972; Powell et al. 1991; and Forbes et al. 1989)
Lack of Complications	(Jennings 1986; Greenfield et al. 1993; Greenfield et al. 1995; Nathason et a. 1973; Benfield et al. 1991; and Stratton et al. 1991)
Lack of Individual Variation	(Nelson 1990; and Johnson et al. 1990)
Lack of Haptic Realism	(Nelson 1990; Calderwood and Ravin 1972; Howells et al. 1973; Greenfield et al. 1995; and Anastakis et al. 1999)
Students Lack Seriousness	(Greenfield et al. 1995)

Anthropanalogous models, like NRPMs, are best suited for use in the integrative level of psychomotor development. Characteristics, such as anatomic fidelity, allow the development of more advanced skills than with NRPMs and also allow for greater cognitive-motor interaction. However, AAMs are incapable of providing an adequate training model for skills such as patient assessment, decision making, and delicate motor skill development, which are goals of the autonomous phase. Despite the evaluation of the use of AAMs for paramedic intubation training, no conclusive study demonstrates that AAMs prepare students for terminal performance in any resuscitative procedure.

Cadavers (CAD)

The training benefits of cadaver models closely mirror those of NRPMs and AAMs with the added benefits of increased haptic and anatomical realism. Fresh human cadavers are among the most realistic models available for resuscitative procedure training (Iserson 1986; Nelson 1990). These models are anatomically and haptically ideal. They also offer some clinical realism. However, the use of this model is restricted by societal pressure, legislation, and rigor mortis,

which limits the time available for procedure performance. Several authors discuss preparations to increase the realism of using fresh chilled and preserved cadavers such as simulated "blood flow" (Jennings 1986) and fluid aspirations (Nelson 1990). The range of procedures that can be adequately trained on a cadaver rivals those that can be performed on live animals or human patients (table 12).

TABLE 12
NELSON'S CADAVER TABLE

Procedures for which cadavers are excellent teaching model:

Airway Management
Endotracheal Intubation
Naso/Oro-pharyngeal Airway placement
Cricothyrotomy

Wound Care
Suturing
Local Anesthesia
Nerve blocks

Chest Procedures
Needle thoracotomy
Thoracostomy
Thoracotomy
Pericardiocentesis

Abdominal Procedures
Nasogastric Tube Placement
Peritoneal lavage

Miscellaneous Procedures
Foley (Urinary) Catheter Placement
Arthrocentesis
Venous cutdown

Procedures for which cadavers are fair to good teaching model:

Central Line Placement
Orthopedic procedures (splinting, casting, reduction)
Intraosseous Infusion

Procedures for which cadavers are poor teaching model:

Peripheral IV Placement
Blood Gas Collection
Abscess I&D
Mouth-to-mouth Resuscitation

Source: (Nelson 1990, 334).

The use of animal tissues for wound repair training is described extensively. Tissues such as pigs' feet and turkey skins offer the advantages of being inexpensive, easily obtained from the grocer, easily stored, and haptically realistic. These models encourage wound closure practice and develop basic psychomotor skills. As such, they offer the advantages of a NRPM with the added benefit of haptic realism, allowing refinement of delicate tissue handling.

Despite these training benefits, cadavers have many characteristics that potentially detract from their use in trauma training. Many students consider working with cadavers, human or animal, to be repulsive or unaesthetic, especially during initial cadaver exposures. This response is more common with human cadavers, but is also noted in students using animal cadavers and animal tissue models. While patients who have just died are excellent training models, the use of recently deceased humans is extremely controversial. Issues of family consent, religious practices, and medical examiner laws limit such use. The risk of communicable disease transmission is also a contemporary detractor from this model's use in training.

Criticism of the cold and clammy, or greasy, skin as well as the lack of haptic realism of chilled or embalmed cadaver tissues is common. Lack of clinical realism is another common characteristic of cadaver models. Cadaver models lack appropriate muscle tone and are difficult to manipulate due to rigor mortis or embalming. Procedure rehearsal on cadavers can be unrealistically easy because lack of hemorrhage allows easy access and visualization of anatomic structures. While many procedures can be adequately trained on cadavers, other procedures are limited in the number of times the procedure can be performed. The performance of chest tube insertion and surgical airway establishment is limited to very few repetitions. Pericardiocentesis cannot be adequately trained on a cadaver (Powers and Draeger 1992). Cadavers are inappropriate for patient assessment and stabilization training because they are static models that lack feedback. In the only study comparing the training value of live animal and cadaver models, Larry Carpenter and others (1991) found that veterinary students developed comparable basic

surgical skills while training on either live anesthetized dogs or the canine cadavers. He also noted that the model was unsuitable for advanced training. Its faults included unrealistic tissue handling, rigor mortis, post mortem change, and lack of feedback from this static, unresponsive model. Similarly, Kenya H. Anders and others (1989) noted that pigs' feet are excellent models for basic skill development, but that they do not emphasize proper tissue handling (Anders et al. 1989). Cadavers are excellent models for procedural training of many critical resuscitative procedures, but they lack the clinical realism necessary to be used as an autonomous level training model or as a proficiency-testing tool.

While lack of clinical realism limits cadaver use as an autonomous level training model, logistical issues tend to limit cadaver suitability as a basic skill development model. The use of cadaver models suffers from accessibility and availability. Cadavers are relatively expensive with an average price of five hundred dollars (Nelson 1990; and Anastakis et al. 1999). Cadaver use requires specialized storage, laboratory, and disposal facilities, just as animals used in training do. Access to cadavers is often limited, making their use by students as a model for frequent, repeated, basic motor skill practice difficult. Robert M. Oneal (1967) and Michael S. Bauer (1993) noted that students appeared to take cadaver model use less seriously or lose attention quickly. Table 13 summarizes the characteristics of cadaver models.

TABLE 13
CADAVER MODEL CHARACTERISTICS

Training Benefit	Citation
Anatomic Realism	(Weaver et al. 1986; Nelson 1990; PCRM n.d.a; Iserson 1986; Jennings et al. 1974; Eaton et al. 1990; Carpenter et al. 1991; Greenfield et al. 1993; Buyukmihci n.d.a; Anastakis et al. 1999; Benfield et al. 1991; and Chapman 1994)
Haptic Realism (Fresh CAD)	(Wolfe et al. 1988; Straith et al. 1961; Oneal et al. 1967; Lawrence and Wiviott 1978; Romm and Berggren 1980; Stotter et al. 1986; Hoffman et al. 1990; and Iserson 1986)
Range of Procedures	(Nelson 1990)
Repetitive Practice	(Weaver et al. 1986; Straith et al. 1961; and Lawrence and Wiviott 1978)
Clinical Realism	
Individual Variation	(Weaver et al. 1986)
Tissue Reaction (Fresh CAD)	(Wolfe et al. 1988)
Inexpensive & Readily Available	(Narwani and Reid 1969; Majeed et al. 1992; Straith et al. 1961; Oneal et al. 1967; Snell 1978; Hoffman et al. 1990; Van Vreeswijk and Pameyer 1998; Coroneo 1990; Jennings 1986; and Bauer 1993)

Training Detractor	Citation
Unaesthetic or Repulsive	(Nelson 1990; Lewis and Nusbaum 1987; Snell 1978; Kass 1985; Carpenter et al. 1991; Holmberg et al. 1993; Holmberg and Cockshutt 1994; Benfield et al. 1991; Oneal et al. 1967; and Bauer 1993)
Socially Controversial	(Pince 1970; Nelson 1990; Iserson 1986, 1991; Culver 1986; Feinberg 1985; Kass 1985; Orlowski 1988, 1989; Stryker 1989; Matz 1989; Morhaim and Heller 1989; Eaton et al. 1990; Jennings 1986; Anastakis et al. 1999; Benfield et al. 1991; and Barnes 1987)
Communicable Disease Risk	(Eaton et al. 1990; Stotter et al. 1986; and Anastakis et al. 1999)
Limited Procedures	(Weaver et al. 1986; Nelson 1990; Eaton et al. 1990; and Powers and Draeger 1992)
Lack of Realism (Embalmed)	(Pince 1970; Weaver et al. 1986; Nelson 1990; Eaton et al. 1990; Lewis and Nusbaum 1987; Carpenter et al. 1991; Bauer 1993; Olsen et al. 1996; Chapman 1994; Reid and Vestrup 1988; Iserson 1986; Calderwood and Ravin 1972; Jennings 1986; Greenfield et al. 1993; Holmberg et al. 1993; and Holmberg and Cockshutt 1994)
Poor Availability / Limited Access	(Henkel et al. 1994; Nelson 1990; Thomas et al. 1996; Klofas 1997; Stotter et al. 1986; Calderwood and Ravin 1972; Holmberg and Cockshutt 1994; and Stratton et al. 1991)
Logistical Issues	(Oneal et al. 1967; Bevan 1981; Coroneo 1990; Eaton et al. 1990; Thomas et al. 1996; Holmberg and Cockshutt 1994; Anastakis et al. 1999; Nelson 1990; Stotter et al. 1986; and Bevan 1986)
Expense	(Nelson 1990; Eaton et al. 1990; and Anastakis et al. 1999)

Nevertheless, cadavers have been used for basic skill development. Animal tissue models offer many of the same advantageous characteristics as other inanimate models with the added benefits of improved anatomic and haptic realism. Lars Wik and others (1997) found no appreciable differences in intubation skills between groups trained on intubation mannequins and cadavers. Similarly, M. E. Weaver and others (1986) designed cadaver laboratories that allowed repetitive basic skill practice until students and instructors were confident of the students' abilities. However, the success of a model in procedural training is meaningless if the model is unavailable for use by the students (Stratton et al. 1991). The biggest problem with the widespread use of human cadavers, fresh or embalmed, is that they are not readily available.

Complex Interactive Mannequins (CIM)

Complex interactive mannequins are designed for use in the training and testing of anesthetists. They offer programmable scenarios varying from simple training routines to challenging testing routines designed to cause student failure (Chopra et al. 1994). The use of simulated operating rooms increases environmental reality, and many simulation centers employ full OR staffs to increase the hustle and bustle around the trainee (Gaba and DeAnda 1989; DeAnda and Gaba 1990, 1991; and Chopra et al. 1994). CIMs are considered realistic enough that they are now being used as a research model. CIMs allow the performance of many procedures to include resuscitative skills (Laerdal n.d.; MPL n.d.; UCLA n.d.; Norman and Wilkins 1996; METI 1997; UW n.d.; Chopra et al. 1994; MedSim 1999; and Abrahamson et al. 1969). Patient complications are presented as difficult airway insertion, laryngospasm, and regurgitation. Their ability to realistically simulate human pharmacophysiologic behavior and response to intervention is unmatched by any other model discussed (Norman and Wilkins 1996). As such, they are the ultimate patient assessment tools available for medical training today. Table 14 summarizes CIM characteristics.

TABLE 14
COMPLEX INTERACTIVE MODEL CHARACTERISTICS

Training Benefit	Citation
Programmable	(Murray and Schneider 1997; Gaba and DeAnda 1989; DeAnda and Gaba 1990, 1991; and Chopra et al. 1994)
Clinical Realism	
Response to Interventions	(Murray and Schneider 1997; Norman and Wilkins 1996; Raemer and Barron 1997; Gaba and DeAnda 1989; DeAnda and Gaba 1990, 1991; Chopra et al. 1994; UW n.d.; and UCLA n.d.)
Environmental	(Gaba and DeAnda 1989; DeAnda and Gaba 1990, 1991; Chopra et al. 1994; Norman and Wilkins 1996; and UW n.d.)
Complications	(Chopra et al. 1994; Laerdal n.d.; UW n.d.; Good 1997; and UCLA n.d.)
Use in Certification	(Gaba and DeAnda 1989; DeAnda and Gaba 1990, 1991; and Chopra et al. 1994)
Training Detractor	Citation
Expense	(Calderwood and Ravin 1972; Norman and Wilkins 1996; Murray and Schneider 1997; and Funk 2000a)
Lack Haptic Realism	(Good 1997)
Not designed for Procedures	(Norman and Wilkins 1996)
Physiological not Physical Realism	(Norman and Wilkins 1996)
Logistics	
Staff	(Norman and Wilkins 1996; and Murray and Schneider 1997)
Dedicated Training Area	(Chopra et al. 1994; and Murray and Schneider 1997)

Despite these advantages, the design of CIMs is a trauma-training detractor. They are designed for anesthetist use in a hospital environment. The CIM is designed to simulate responses to anesthetist action. These models allow a number of physical and medical interventions; however, patient response to intervention is measured via output on a monitor instead of by hands-on physical examination (Norman and Wilkins 1996). Procedures may be performed on the mannequin, but such performance is not designed to be realistic. The mannequins lack haptic realism, and procedure performance, such as chest tube insertion, may be done through a pre-formed port. The performance of the procedure is simply another way to register a response in the computer program. The clinical realism for the trauma responder is negligible. It appears that less expensive CIMs (advanced AAMs) will offer trauma features and more realistic procedural

performance. CIMs are designed to provide interactive cognitive and problem solving training, or to more realistically allow the performance of resuscitative procedures, but not both (Raemer and Barron 1997). Currently, no single CIM allows both the performance of resuscitative procedures and the patient assessment.

In their glowing review of CIM capabilities, W. Bosseau Murray and Arthur J. L. Schneider (1997) also emphasize their two biggest disadvantages. Commercial simulators cost between $80,000 and $200,000, and operational costs average $500 per hour due to simulator staffing requirements. The expense of these simulators has limited their use to just over 50 sites nationwide. These simulators require staffs, special facilities, and substantial maintenance. Again, these considerations are common to cadavers and live animals. Access to CIMs is very limited. As with cadavers, if access is extremely limited, the viability of a model as a replacement alternative is questionable.

Animal Models

The most commonly cited training benefit of animal model use is the characteristic of clinical realism. Clinical realism includes characteristics such as biological variation, increased level of difficulty, the presence of patient and procedural treatment complications, environmental realism, the creation of stress or a sense of urgency, and the dynamic nature of the animal model. No other model offers this degree of clinical realism. Increased procedural difficulty solidifies previous learning experiences, forces problem solving, and increases skill retention. Cats have long been used as intubation models because their characteristic laryngospasm and salivation make intubation practice more difficult than actually intubating human patients (Calderwood and Ravin 1972; and Jennings et al. 1974). Patient complications such as biologic variations, movement, individual anatomic variation, bleeding and laryngospasm, make performance both more realistic and more difficult by complicating treatments, forcing decision making, and

offering different visual cues. T. O. Henkel and others (1994) note that the most important difference between a simulator and an animal model is the presence and proper handling of complications. Training on animals produces stress, anxiety, and urgency, since the patient is alive, and the student knows that inappropriate treatment will produce immediate negative feedback. Environmental realism increases the challenging nature of the experience by providing distractions and increasing the demands on the student's problem solving abilities. Meaningfulness of the training event increases skill retention (Kaufman et al. 1987). If "retention of knowledge can only be accomplished through repetition of an exceptionally vivid learning experience," then animal model use is the ideal learning experience (Krahwinkel 1977, 102).

Haptic realism is another important characteristic of animal models. Live animals improve fine motor skills by offering haptic realism and tissue reaction to instrumentation. Precise tissue handling, tissue reaction to handling, and the results of poor hemostasis are best conveyed on the live animal model (Smeak et al. 1991).

Animals are the models of choice for terminal performance certification. Animals allow the creation of challenging, realistic, and dynamic scenarios that engage students and shift the burden of decision-making responsibility to the student. Animals also provide immediate positive and negative feedback for appropriate and inappropriate intervention. Animal models have proven beneficial in improving the identification of marginal performers, and have been validated as a thoracotomy testing model (Mattsson et al. 1980; Watson et al. 1982; and Chapman et al. 1996). Table 15 summarizes the characteristics of animal models used in training.

TABLE 15
ANIMAL MODEL CHARACTERISTICS

Training Benefit	Citation
Clinical Realism	
Level of Difficulty	(Henkel et al. 1994; Calderwood and Ravin 1972; and Forbes et al. 1989)
Individual Variability	(Knudsen and Darre 1996; Mattsson et al. 1980; Smeak et al. 1991; and Calderwood and Ravin 1972)
Complications	(Kopchok et al. 1993; Henkel et al. 1994; Watson et al. 1982; Klausner et al. 1987; Nelson 1990; Mattsson et al. 1980; Gimpleson et al. 1989; Smeak et al. 1991; Tugsel 1992; Calderwood and Ravin 1972; Jennings et al. 1974; and Forbes et al. 1989)
Dynamic Model	(Klausner et al. 1987; Sternbach and Rosen 1977; Knudsen and Darre 1996; Mattsson et al. 1980; Henkel et al. 1994; Anastakis et al. 1999; Calderwood and Ravin 1972; Gimpleson et al. 1989; and Smeak et al. 1991)
Environmental Realism	(Johnson and Farmer 1989; and Smeak et al. 1991)
Stress & Urgency	(Klausner et al. 1987; Rosin 1986; Homan et al. 1994; and Smeak et al. 1991)
Haptic realism	(Klausner et al. 1987; Mattsson et al. 1980; Kopchok et al. 1993; Owen et al. 1987; Rosin 1986; Anders et al. 1989; Carpenter et al. 1991; and Smeak et al. 1991)
Student Responsibility	(Klausner et al. 1987; Mattsson et al. 1980; Watson et al. 1982; and Carpenter et al. 1991)
Assessment and Feedback	(Mattsson et al. 1980; Henkel et al. 1994; Woods et al. 1980; and Watson et al. 1982)
Testing Vehicle	
ID of Poor Performers	(Mattsson et al. 1980; Watson et al. 1982; and Chapman et al. 1996)
Crisis Situations	(Mattsson et al. 1980; Watson et al. 1982; and Klausner et al. 1987)
Challenge Scenarios	(Klausner et al. 1987; and Watson et al. 1982)
Increased Confidence	(Klausner et al. 1987; Sternbach and Rosen 1977; Mattsson et al. 1980; Olshaker et al. 1989; Woods et al. 1980; Lossing, Hatswell, et al. 1992; Calderwood and Ravin 1972; Jennings et al. 1974; Gillette 1976; Bauer, Glickman, Glickman, et al. 1992)
Training Detractor	Citation
Lack Anatomic Realism	(Pince 1970; Sternbach and Rosen 1977; Nelson 1990; PCRM n.d.a; Jennings et al. 1974; Smeak 1989; Homan et al. 1994; Anastakis et al. 1999; and Chapman 1994)
Zoonotic Disease Risk	(Stotter et al. 1986)
Negative Social Pressures	(Pince 1970; Nelson 1990; Smeak 1989; Rollin 1990; Klofas 1997; Rogers et al. 1986; PCRM n.d.a; Schantz 1979; Swindle 1984; Rosin 1986; Gambardella 1986; Carpenter et al. 1991; Steffens et al. 1992; DeYoung and Richardson 1987; Greenfield et al. 1993; Bauer 1993; Olsen et al. 1996; Johnson and Farmer 1989; Lossing, Hatswell, et al. 1992; Will 1984; and Barnes 1987)
Limited Exposure	(Sinclair 1984; Smeak 1989; Bauer, Glickman, Glickman, et al. 1992; Olsen et al. 1996; and Smeak et al. 1991)
Prohibitions (UK & Europe)	(Stotter et al. 1986; Eaton et al. 1990; Majeed et al. 1992; Byrne 1994; Hoffman et al. 1990; Lossing, and Hatswell et al. 1992)
Complex Regulations	(Smeak 1989; Smeak et al. 1991; Steffens et al. 1992; Benfield et al. 1991; and Will 1984)
Tissue Handling Differences	(Eggerston 1983; and Sternbach and Rosen 1977)
Monetary Considerations	(Pince 1970; Eggerston 1983; Sinclair 1984; Smeak 1989; Rollin 1990; Rogers et al. 1986; Stotter et al. 1986; Anders et al. 1989; Carpenter et al. 1991; Greenfield et al. 1993; Bauer 1993; Olsen et al. 1996; Benfield et al. 1991; and Lossing, Hatswell, et al. 1992)
Logistical Considerations	(Eaton et al. 1990; Sinclair 1984; PCRM n.d.a; DeYoung and Richardson 1987; Tugsel 1992; Kopchok et al. 1993; Stotter et al. 1986; Schantz 1979; Swindle 1984; Smeak 1989; Bauer 1993; Benfield et al. 1991; Gimpleson et al. 1989; Anders et al. 1989; Eaton et al. 1990; and Steffens et al. 1992)

These characteristics are all consistent with performance at the autonomous level of development. The animal model offers clinical and haptic realism, challenge, increased student responsibility for decision making, positive and negative feedback, and an ideal testing vehicle. Ultimately, live animal use allows autonomous level performance, producing a trauma responder who is competent, confident, and capable of acting without supervision.

Many of the characteristics which make animals excellent models for advanced training and terminal proficiency testing also make them inappropriate models for developing basic skills. Gilroy P. Bevan (1981) states that animal models detract from basic skill development. Several educators agree that early progression to animals leads to negative surgical experiences, frustration, and poor confidence. Basic skills are better learned on models (Smeak 1989; Johnson and Farmer 1990; Smeak et al. 1991; Henkel et al. 1994; and DeYoung and Richardson 1987). Additionally, animal use offers limited exposure so that students get inadequate practice opportunities to allow the development of basic skills. Many veterinary researchers have documented superior performance of basic skills in groups trained on models as opposed to groups trained using live animals. Such outcomes are more a result of the increased practice opportunities afforded by inanimate models as compared to animal models, than they are a reflection of the model's training value (Smeak et al. 1991; Carpenter et al. 1991; and Greenfield et al. 1995). Joel Mattsson (1980, 401) discusses the prerequisite skill level of a candidate for animal facilitated trauma training, noting that "access to the animal laboratory should be limited to those prepared for advanced training," since the lab is best suited to refinement of previously learned skills, and gaining speed and confidence.

The two most commonly cited training detractors of animal models are negative social pressures towards animal use in training and the increasing cost of using animals. Other detractors include anatomic differences between animal models and man, tissue handling differences, limited student exposure opportunities, the potential for zoonotic disease

transmission, increasing regulatory restrictions, and logistical considerations. Negative social pressure has had a tremendous impact on the perception and regulation of animal use in training, as already discussed. Animals suffer from lack of anatomic realism in many instances. The classic example is the conduct of venous cutdown on the lateral aspect of the animal's leg, while it is performed on the medial aspect of the human leg. Chest shape also effects the performance of procedures such as chest tube insertion and pericardiocentesis. While anatomic infidelity is a criticism of animal models, Robert B. Forbes and others (1989) note that for some exercises, animals are anatomically realistic and more appropriate than other models.

Animal use in training is also expensive. Individual animals are relatively expensive, and animal use requires a substantial logistical investment. Animal use requires specialized holding and laboratory facilities. Animal use also requires special staffing to include animal caretakers and veterinary oversight. These logistical considerations are not unlike those placed upon cadaver use. All advantages and disadvantages are relative to the current situation and training scenario. The necessity to have special staff and facilities for the use of animals might be considered a training detractor. However, if the training institution already has the staff and facilities to accommodate animal facilitated training, these perceived disadvantages of animal use do not apply. These same logistical, ethical, and legal considerations occur in the decision to use cadavers in training.

The investigation of using alternative methods to replace traditional live animal laboratories in veterinary surgical education is well published. The use of cadavers (Carpenter et al. 1991; and Bauer, Glickman, Glickman, et al. 1992), NRPMs (Smeak 1989; and Smeak et al. 1990), and AAMs (DeYoung and Richardson 1987; Johnson and Farmer 1989; Johnson et al. 1990; Greenfield et al. 1993; Greenfield et al. 1995; Greenfield et al. 1994; Holmberg and Cockshutt 1994; and Holmberg et al. 1993) is discussed. It is important to note that none of these authors suggests that alternative methods might replace live animal use in surgical training. Each

of these articles describes alternative use for the development of basic skills so that the student might be better prepared for his first live animal training experience and benefit more greatly from it (Bauer 1993; Smeak 1989; Greenfield et al. 1994; and Johnson and Farmer 1989). All have progression from basic skill development using inanimate models to advanced skill development using live animals as an underlying assumption. These authors consistently discuss alternative methods in training as a means of reduction rather than replacement. Similar discussions are seen in human surgical literature (Steffens et al. 1992). Despite their deliberate articulation of this point, these studies are frequently misinterpreted as evidence to support the total replacement of animals with alternate models.

Niches

Niche analysis establishes the most appropriate role for models in trauma training by evaluating the characteristics of each model group in light of the principles of psychomotor skill development. The cognitive level develops mental skills, but not motor skills. Models that are interactive and maintain attention increase learning during this phase of training. NRMs are appropriate for cognitive phase training, but play little role in the development of motor skills. The integrative level of procedural psychomotor development is the phase in which the student develops dexterity and hand-eye coordination. This phase is characterized by frequent repetition of appropriate basic motor skills. NRPMs, AAMs, and cadavers fill this niche. Model realism is much less important than the opportunity for frequent practice. The autonomous level of psychomotor development is characterized by manual competence, motor skill refinement, ability to perform when challenged, and increased decision-making responsibilities. The treatment of traumatic emergencies requires autonomous level performance, so that resuscitative skills can be performed automatically, and the responder's full attention can be focused on assessment of the patient and his response to interventions. Training at this level must be challenging and realistic.

Only CIMs and animal models allow training at this level of development. Animal models are also ideally suited for terminal performance competency testing. Figure 2 offers a graphic representation of the results of this niche analysis for trauma training models.

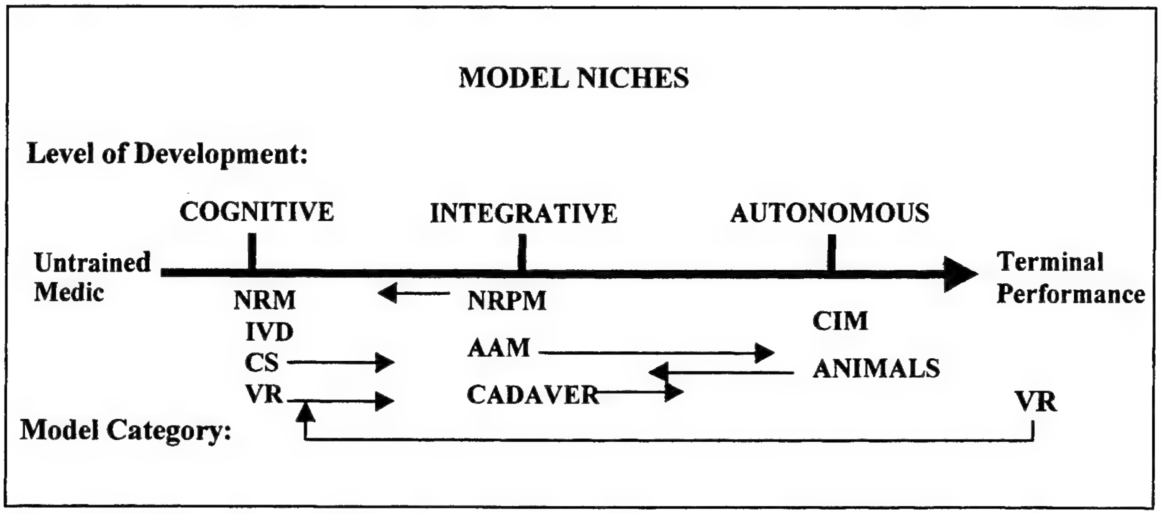

Figure 2. Training Model Niches.

Event-Totality Standard Analysis

An Event-Totality Standard was used to determine if inanimate models could, individually or collectively, replace the use of animals in trauma training. Previously, the niche of animals was determined to be training at the autonomous level or in proficiency testing before terminal performance. The ETS is comprised of patient assessment and stabilization, airway management to include orotracheal intubation and surgical airways, peritoneal lavage, pericardiocentesis, peripheral venous access to include catheterization and venous cutdown, hemorrhage control, chest decompression to include needle and tube thoracotomy, and wound management to include laceration repair and fracture stabilization. First a superficial analysis was performed to ascertain whether models were available to allow the training of each procedure using alternate methods. Next, the models identified for use in training each procedure were analyzed to determine if they would provide the student with training comparable to that provided

by the animal model. This involved the application of the previously discussed niche analysis results alongside the superficial ETS analysis results. The ability of an inanimate model to facilitate procedural training, but at a lower level of training than does the animal model, fails to satisfy the "comparable training value" criterion for animal use replacement. Finally, models fulfilling the ETS were assessed for practical considerations that might impact their ability to be used in trauma training. Table 16 summarizes the results of ETS analysis, identifying models for the training of each procedure.

TABLE 16
EVENT-TOTALITY STANDARD

Patient Assessment / Stabilization	Category	Citation
Live Dog	Animal	(Mattsson et al. 1980)
Live Pig	Animal	(Knudsen and Darre 1996)
Mannequins (Computerized)	AAM	(MPL n.d.)
MPL Head & Neck Trauma Exam Model	AAM	(Maroon and Gosling 1973)
ALS Skillmaster Manikin/HeartSim 4000	CIM	(Laerdal n.d.)
Complete Care Doll (GDW-2600)	CIM	(MPL n.d.)
Gainsville Anesthesia Simulator	CIM	(Norman and Wilkins 1996; and UF 1996)
Human Patient Simulator	CIM	(UCLA n.d.)
Human Patient Simulator (CAE)	CIM	(Norman and Wilkins 1996)
Human Patient Simulator (METI)	CIM	(METI 1997; Mount Sinai n.d.; and UW n.d.)
Leiden Anesthesia Simulator	CIM	(Chopra et al. 1994; and UW n.d.)
Mega-Code ACLS Trainer "Delux Plus"	CIM	(MPL n.d.; and Funk 2000b)
PatientSim	CIM	(MedSim 1999)
SimOne (Univ Calif)	CIM	(Abrahamson et al. 1969)

Tube Thoracotomy	Category	Citation
Live Canine	Animal	(Sternbach and Rosen 1977; Mattsson et al. 1980; Thompson et al. 1984; Klausner et al. 1987; and ACS 1997)
Live Pig	Animal	(Olshaker et al. 1989; and ACS 1997)
Live Goat	Animal	(ACS 1997; and Tortella et al. 1996)
Live Primate	Animal	(Sims 1979)
Thoracotomy Model	NRPM	(Sinclair 1984; and Blumenfeld et al. 1997)
Coconut & Balloon	NRPM	(Anastakis et al. 1999)
DAISE	AAM	(Anastakis et al. 1999)
Mannequins	AAM	(Hill 1993)
Animal CAD	CAD	(Eaton et al. 1990; and Anastakis et al. 1999)
Human CAD	CAD	(Weaver et al. 1986; Powers and Draeger 1992; and PCRM 1997)
Human Patient Simulator (METI)	CIM	(METI 1997)
PatientSim	CIM	(MedSim 1999)

TABLE 16 (CONTINUED)

Cricothyrotomy / Tracheotomy	Category	Citation
Live Dog	Animal	(Sternbach and Rosen 1977; Mattsson et al. 1980; Thompson et al. 1984; Klausner et al. 1987; Homan et al. 1994; and ACS 1997)
Live Pig	Animal	(Olshaker et al. 1989; Knudsen and Darre 1996; and ACS 1997)
Live Goat	Animal	(ACS 1997; and Tortella et al. 1996)
Live Primate	Animal	(Sims 1979)
Live Cat	Animal	(McLaughlin and Iserson 1986)
Basic Cric Trainer (AA-9425)	NRPM	(AMI n.d.)
Cricothyroid Model	NRPM	(Blumenfeld et al. 1997)
Mannequins	AAM	(Powers and Draeger 1992; Hill 1993; and AMI n.d.)
Human CAD	CAD	(Nelson 1990; Iserson 1991; Johnson et al. 1993; and PCRM 1997)
Animal CAD	CAD	(Eaton et al. 1990; and McLaughlin and Iserson 1986)
Complete Care Doll (GDW-2600)	CIM	(MPL n.d.)
Gainsville Anesthesia Simulator	CIM	(Norman and Wilkins 1996)
Human Patient Simulator (CAE)	CIM	(Norman and Wilkins 1996)
Human Patient Simulator (METI)	CIM	(METI 1997)
Mega-Code ACLS Trainer "Delux Plus"	CIM	(MPL n.d.)
PatientSim	CIM	(MedSim 1999)

Needle Thoracotomy	Category	Citation
Live Canine	Animal	(Mattsson et al. 1980; and ACS 1997)
Live Pig	Animal	(ACS 1997)
Live Goat	Animal	(ACS 1997)
Live Primate	Animal	(Sims 1979)
Animal CAD	CAD	(Eaton et al. 1990)
Human CAD	CAD	(Weaver et al. 1986; Nelson 1990; and Iserson 1991)
Human Patient Simulator (METI)	CIM	(METI 1997.)
Mega-Code ACLS Trainer "Delux Plus"	CIM	(MPL n.d.)
PatientSim	CIM	(MedSim 1999)

Intubation	Category	Citation
Live Dog	Animal	(Sternbach and Rosen 1977; and Mattsson et al. 1980)
Live Pig	Animal	(Forbes et al. 1989; and Knudsen and Darre 1996)
Live Ferret	Animal	(Powell et al. 1991)
Live Cat	Animal	(Calderwood and Ravin 1972; Jennings et al. 1974; and Woods et al. 1980)
Mannequins	AAM	(Howells et al. 1973; Stewart et al. 1984; Klausner et al. 1987; Forbes et al. 1989; Nelson 1989, 1990; Stratton et al. 1991; Powers and Draeger 1992; Hill 1993; Van Stralen et al. 1995; Wik et al. 1997; MPL n.d.; Laerdal n.d.; Ambu USA n.d.; and AMI n.d.)
Human CAD	CAD	(Iserson 1986, 1991; Orlowski 1988; Nelson 1990; Stern and Spitzer 1991; Stratton et al. 1991; and Benfield et al. 1991)
ALS Skillmaster Manikin/HeartSim 4000	CIM	(Laerdal n.d.)
Complete Care Doll (GDW-2600)	CIM	(MPL n.d.)
Gainsville Anesthesia Simulator	CIM	(Norman and Wilkins 1996)
Human Patient Simulator	CIM	(UCLA n.d.)
Human Patient Simulator (CAE)	CIM	(Norman and Wilkins 1996)
Human Patient Simulator (METI)	CIM	(METI 1997; and UW n.d.)
Leiden Anesthesia Simulator	CIM	(Chopra et al. 1994; and UW n.d.)
Mega-Code ACLS Trainer "Delux Plus"	CIM	(MPL n.d.)
PatientSim	CIM	(MedSim 1999)
SimOne (Univ Calif)	CIM	(Abrahamson et al. 1969)

TABLE 16 (CONTINUED)

Pericardiocentesis	Category	Citation
Live Dog	Animal	(Thompson et al. 1984; Klausner et al. 1987; Homan et al. 1994; and ACS 1997)
Live Pig	Animal	(Olshaker et al. 1989; Knudsen and Darre 1996; and ACS 1997)
Live Goat	Animal	(ACS 1997)
Live Primate	Animal	(Sims 1979)
Human CAD	CAD	(Weaver et al. 1986; Nelson 1990; and PCRM 1997)
Human Patient Simulator (METI)	CIM	(METI 1997)

Peritoneal Lavage	Category	Citation
Live Dog	Animal	Sternbach and Rosen 1977; Thompson et al. 1984; Homan et al. 1994; and ACS 1997)
Live Pig	Animal	(Olshaker et al. 1989; Knudsen and Darre 1996; and ACS 1997)
Live Goat	Animal	(ACS 1997; and Tortella et al. 1996)
Live Primate	Animal	(Sims 1979)
Human CAD	CAD	(Nelson 1990; Iserson 1991; and PCRM 1997)

Venous Catheterization	Category	Citation
Live Canine	Animal	(Homan et al. 1994)
Live Pig	Animal	(Knudsen and Darre 1996)
CathSim Training System	NRPM	(HT 1998a)
Advanced 4 Vein Venipuncture Arm Pad	NRPM	(AMI n.d.)
Commercial IV Arms	AAM	(MPL n.d.; Laerdal n.d.; Ambu USA n.d.; and AMI n.d.)
Mannequins	AAM	(Klausner et al. 1987; and Nelson 1990)
Animal CAD	CAD	(Capperauld and Hargraves 1991)
Human CAD	CAD	(Iserson 1986; Reid and Vestrup 1988; and Iserson 1991)
ALS Skillmaster Manikin/HeartSim 4000	CIM	(Laerdal n.d.)
Human Patient Simulator (METI)	CIM	(METI 1997)
Leiden Anesthesia Simulator	CIM	(Chopra et al. 1994)
Mega-Code ACLS Trainer "Delux Plus"	CIM	(MPL n.d.)
PatientSim	CIM	(MedSim 1999)
SimOne (Univ Calif)	CIM	(Abrahamson et al. 1969)

Venous Cutdown	Category	Citation
Live Canine	Animal	(Sternbach and Rosen 1977; and Mattsson et al. 1980; Thompson et al. 1984; Klausner et al. 1987; and ACS 1997)
Live Pig	Animal	(Olshaker et al. 1989; and ACS 1997)
Live Goat	Animal	(ACS 1997; and Tortella et al. 1996)
Live Primate	Animal	(Sims 1979)
Venous Cutdown Model	NRPM	(Eggerston 1983; and Klofas 1997)
Laerdal Venous Cutdown Model	AAM	(Laerdal n.d.)
Sawbones Ankle Model	AAM	(PRL n.d.)
Animal CAD	CAD	(Capperauld and Hargraves 1991)
Human CAD	CAD	(Weaver et al. 1986; Nelson 1990; and PCRM 1997)

TABLE 16 (CONTINUED)

Hemorrhage Control	Category	Citation
Live Canine	Animal	(Watson et al. 1982; Rosin 1986 ; Klausner et al. 1987; Carpenter et al. 1991; Smeak et al. 1991; Lossing, Hatswell, et al. 1992; and Olsen et al. 1996)
Live Rabbit	Animal	(Boothe and Hartsfield 1990)
Live Pig	Animal	(Lossing, Hatswell, et al. 1992; and Knudsen and Darre 1996)
Fluid Hemostasis Model	NRPM	(Bauer and Seim 1992; and Olsen et al. 1996)
Foam Models	NRPM	(Lossing, Hatswell, et al. 1992)
Foam, Carpet, Yarn	NRPM	(Bauer 1993)
Ligation Model	NRPM	(Smeak 1989; and Smeak et al. 1991)
Perineal Tear Model	NRPM	(Cain and Shirar 1996)
Abdominal Organ Model	AAM	(Greenfield et al. 1993; Bauer 1993; and Greenfield et al. 1995)
DAISE	AAM	(Holmberg et al. 1993; and Holmberg and Cockshutt 1994)
Simulated Appendectomy Model	AAM	(Lossing and Groetzsch 1992)
Animal CAD	CAD	(Carpenter et al. 1991)

Wound Management	Category	Citation
Live Rabbit	Animal	(Boothe and Hartsfield 1990)
Live Canine	Animal	(Sternbach and Rosen 1977; Mattsson et al. 1980; Rosin 1986; Carpenter et al. 1991; and Olsen et al. 1996)
Live Pig	Animal	(Kerrigan et al. 1986; and Gormley 1990)
"Skilltray"	NRPM	(Thomas et al. 1996)
Abdominal Jig	NRPM	(Hill and Kiff 1990)
Electric Suturing Board	NRPM	(Bauer and Seim 1992; and Olsen et al. 1996)
Foam Models	NRPM	(Lossing, Hatswell, et al. 1992)
Foam, Carpet, Yarn	NRPM	(Bauer 1993)
Gapefruit Skin	NRPM	(Straith et al. 1961)
Ligation Model	NRPM	(Smeak et al. 1991)
Perineal Tear Model	NRPM	(Cain and Shirar 1996)
Skin Jig	NRPM	(Southern and Browning 1995)
Stoma Jig	NRPM	(Jones and Thompson 1988)
Tie and Suture Board	NRPM	(Boyle and Guis 1968)
VaraDerm: Skin Model	NRPM	(Lewis and Nusbaum 1987)
Veterinary Teaching Models	NRPM	(Greenfield et al. 1994)
Sticks, Ropes, Rods	NRPM	(Johnson and Farmer 1989)
Suturing Arm	AAM	(AMI n.d.)
Abdominal Organ Model	AAM	(Greenfield et al. 1993; Bauer 1993; and Greenfield et al. 1995)
DAISE	AAM	(Holmberg et al. 1993; Holmberg and Cockshutt 1994; and Anastakis et al. 1999)
Dental Models	AAM	(Meyer et al. 1989)
Mannequins	AAM	(MPL n.d.; PRL n.d.; and Laerdal n.d.)
Simulated Appendectomy Model	AAM	(Lossing and Groetzsch 1992)
Pigs Ear	CAD	(Romm and Berggren 1980)
Turkey Skin	CAD	(Lawrence and Wiviott 1978
Pigs Feet	CAD	(Straith et al. 1961; Oneal et al. 1967; Graham 1974; Snell 1978; and Anders et al. 1989)
Animal CAD	CAD	(Gormley 1990; and Capperauld and Hargraves 1991; Greenfield et al. 1994)
Human CAD	CAD	(Gormley 1990; Nelson 1990; and Anastakis et al. 1999)
Complete Care Doll (GDW-2600)	CIM	(MPL n.d.)
Mega-Code ACLS Trainer "Delux Plus"	CIM	(MPL n.d.)

TABLE 16 (CONTINUED)

Fracture Stabilization	Category	Citation
Live Rabbit	Animal	(Boothe and Hartsfield 1990)
Live Pig	Animal	(Knudsen and Darre 1996)
Bone Models	NRPM	(Lippert and Farmer 1984)
Sticks, Ropes, Rods	NRPM	(Johnson and Farmer 1989)
Mannequins	AAM	(MPL n.d.)
Synthetic Bones	AAM	(Neimkin et al. 1983; DeYoung and Richardson 1987; Anastakis et al. 1999; and PRL n.d.)
Animal CAD	CAD	(Greenfield et al. 1994; and Jennings 1986)
Human CAD	CAD	(Lippert et al. 1975; and Nelson 1990)
PatientSim	CIM	(MedSim 1999)

Superficial Event-Totality Standard analysis was performed merely to identify the models available for the training of each ETS procedure. Superficially, the inanimate models identified in this study satisfy the ETS. While no single model or model class can satisfy the ETS, collectively the identified models can be used to perform each of the required procedures. NRPMs were identified which enabled training of surgical airway, tube thoracotomy, venous catheterization, venous cutdown, hemorrhage control, wound management, and fracture stabilization training. No NRPMs allowed the performance of patient assessment and stabilization, intubation, peritoneal lavage, pericardiocentesis, or needle thoracotomy. AAMs allowed the performance of patient assessment and stabilization, intubation, surgical airway, tube thoracotomy, venous catheterization, venous cutdown, hemorrhage control, wound management, and fracture stabilization. AAMs were not available for training peritoneal lavage, pericardiocentesis, or needle thoracotomy. Cadaver descriptions indicated the performance of every ETS procedure except for patient assessment and stabilization. Finally, the literature has described the use of CIMs for training every procedure except for peritoneal lavage, hemorrhage control, and venous cutdown. On superficial analysis, the identified models collectively satisfy the Event-Totality Standard (table 17).

TABLE 17 EVENT-TOTALITY STANDARD--SUPERFICIAL ANALYSIS					
PROCEDURE	NRPM	AAM	CAD	CIM	ANIMAL
Patient Assessment / Stabilization		✓		✓	✓
Intubation		✓	✓	✓	✓
Cricothyrotomy / Tracheotomy	✓	✓	✓	✓	✓
Peritoneal Lavage			✓		✓
Pericardiocentesis			✓	✓	✓
Needle Thoracotomy			✓	✓	✓
Tube Thoracotomy	✓	✓	✓	✓	✓
Venous Catheterization	✓	✓	✓	✓	✓
Venous Cutdown	✓	✓	✓		✓
Hemorrhage Control	✓	✓	✓		✓
Wound Management	✓	✓	✓	✓	✓
Fracture Stabilization	✓	✓	✓	✓	✓

Next, niche analysis was applied alongside the ETS to determine if the identified models could provide training comparable to that provided by animals. Animal models are used to train each of the ETS procedures at the autonomous level or as a terminal performance-testing vehicle. Other models must allow for training at the autonomous level or use as a terminal performance testing tool if they are to satisfy the ETS and replace the animal use.

<u>Patient assessment and stabilization</u>. Patient assessment and stabilization can be performed on AAMs and CIMs. This is definitely a task that must be trained at the autonomous level. CIMs allow patient assessment via monitors, but do not allow for realistic procedural performance or hands-on patient assessment. CIMs allow the simulation, but not performance of fluid resuscitation and stabilization. AAMs, which allow patient assessment, are full-scale mannequins with computerized ACLS program simulations. These programs are not designed for

trauma simulation. These models do, however, allow for the performance of many more resuscitative procedures than do CIMs.

Intubation. Intubation can be performed on AAMs, CADs, and CIMs. Intubation practice using these models is as good as, or better than, intubation practice on an animal because of the animal model's anatomic differences. However, studies indicate that pediatric intubation training on cats is better than on mannequins due to the cat's anatomic fidelity, and complications such as laryngospasm and salivation, which increase the difficulty of the practice intubation. CIMs offer difficult airway scenarios which provide complications such as regurgitation and laryngospasm. The evidence suggests that intubation training on any of these models is acceptable as preparation for terminal performance.

Surgical Airway. Cricothyrotomy and tracheotomy training has been described using models from all groups. In reality, CIM and AAM surgical airway simulations are the same. Cadavers offer increased anatomic realism, while the NRPMs described offer decreased anatomic realism. Marc S. Nelson (1990) and M. E. Weaver (1986) note that performance of this procedure is limited to a few repetitions in the cadaver model. Nevertheless, all of these models offer sufficient realism to allow the training of this procedure. All of these models provide adequate training value as preparation for terminal performance.

Peritoneal Lavage. Peritoneal lavage is described using a cadaver model. Marc Nelson (1989) rates peritoneal lavage performance on the cadaver as excellent. Kenneth V. Iserson (1991) notes that this procedure can only be performed on recently deceased patients. The evidence is inconclusive concerning the appropriateness of the cadaver as an autonomous training model or preparation for terminal performance.

Pericardiocentesis. Pericardiocentesis can be performed on either CAD or CIM models. Performance on the METI Human Patient Simulator (METI 1997) is mentioned, but neither described nor evaluated. Nelson (1989) rates pericardiocentesis performance on the cadaver as

excellent, while Weaver (1986) describes the cadaver as an inappropriate model for training this procedure. The evidence does not conclusively supporting the use of either cadavers or CIMs for the training of this procedure.

Needle Thoracotomy. Needle thoracotomy training is described using both CAD and CIM models. Again, performance of this procedure on the METI HPS (METI 1997) is mentioned, but neither described nor evaluated. Nelson rates performance of this procedure on the cadaver as excellent. Needle thoracotomy can be trained to a terminal performance proficiency level using the CAD model (Nelson 1989).

Tube Thoracotomy. Tube thoracotomy performance is described for models from each of the groups. This procedure can only be performed a limited number of times on the cadaver model but its performance is rated as excellent (Nelson 1989). AAMs and NRPMs were also identified which allow the performance of this procedure. Performance of tube thoracotomy on CIMs is not always realistic, as the training intent is to produce an appropriate physiological patient response, rather than insure procedure performance fidelity.

Venous Catheterization. Venous catheterization training can be performed with models from each of the groups. Performance on cadavers requires model preparation to allow "bloodflow" (Nelson 1989). This model is not considered adequate preparation for terminal performance. Neither is preparation using NRPMs considered adequate training due to lack of anatomic realism. Venous catheterization training using AAMs has long been the standard of performance before progression to live human patients. CIMs which use AAM venipuncture arms are also adequate training for terminal performance of venous catheterization. However, not all CIMs have arms allowing venipuncture.

Venous Cutdown. This procedure can be trained using NRPMs, AAMs, and cadavers. NRPMs used to train this procedure are designed for developing basic skills and are not adequate for autonomous performance (Eggerston 1983; and Klofas 1997). A newly designed AAM for

training this procedure has been described in commercial literature, but the effectiveness of this model has not been established (Laerdal n.d.). Brian D. Eaton (1990) notes that performance of this procedure on a cadaver model is inadequate to develop the skills required for terminal performance and suggests training this proceed on live animals or humans with varicose veins. Currently, the evidence does not suggest the use of any of these models is appropriate for autonomous level training or for terminal performance testing.

Hemorrhage Control. NRPMs, AAMs, and CADs are all used for hemorrhage control training. Currently, all of these models are used to train basic ligation skills. Terminal performance in this task implies the ability to control active arterial hemorrhage. Currently, only live animals models are adequate for training this task at the autonomous level or providing for competency testing. NRPMs such as Michael S. Bauer and Howard B. Seim's hemostasis training model hold great promise for the future.

Wound Management. Wound management training can be performed with models from each of the groups. Both evidence and practical experience suggest that suturing skills can be trained to a skill level allowing terminal performance using models from any of these groups. CIM operators might be reluctant to allow such training on their human patient simulators due to maintenance costs. Wound management-training models allowing more than simple laceration closures are rare. AAM manufacturers produce mannequin moulage kits that allow the visual characterization of wounds. NRPMs and CADs allow dissection and layered closures, although problems with anatomic and haptic fidelity are noted. Only live animals allow training for severe wound treatment such as gunshot wound debridement or amputation (Knudsen and Darre 1996).

Fracture Stabilization. This procedure can be trained using models from each of the groups. NRPMs are used for learning the basic principles of fracture reduction and stabilization; however, they are inappropriate for autonomous level training. CAD, AAM, and CIM models offer realistic representations of broken limbs, which allow palpation, fracture characterization,

and stabilization. These models lack a degree of clinical realism in that they do not offer crepitus upon palpation; nevertheless, they have been used for years to prepare students for terminal level performance of this task. CTLS simulates this procedure using an uninjured human leg. It is arguable that this model is truly the best stabilization for fracture stabilization training (Blumenfeld et al. 1997).

When model niches are considered in order to ensure a comparable level of training as would be provided using an animal model, the Event-Totality Standard is not fulfilled. The use of animals for training the less invasive procedures, which tend to be more commonly performed by civilian healthcare providers, can possibly be replaced by inanimate models without the loss of training value. Patient assessment and stabilization, peritoneal lavage, pericardiocentesis, venous cutdown, and hemorrhage control are procedures for which there are currently no inanimate models available providing comparable training to that provided by animal models. Table 18 summarizes these findings.

TABLE 18
EVENT-TOTALITY STANDARD--NICHE ANALYSIS

PROCEDURE	NRPM	AAM	CAD	CIM	ANIMAL
Patient Assessment / Stabilization		?		?	✓
Intubation		✓	✓	✓	✓
Cricothyrotomy / Tracheotomy	✓	✓	✓	✓	✓
Peritoneal Lavage			?		✓
Pericardiocentesis			?	?	✓
Needle Thoracotomy			✓	?	✓
Tube Thoracotomy	✓	✓	✓	?	✓
Venous Catheterization	?	✓	?	✓	✓
Venous Cutdown	?	?	?		✓
Hemorrhage Control	?	?	?		✓
Wound Management	✓	✓	✓	✓	✓
Fracture Stabilization	?	✓	✓	✓	✓

The proceeding does not imply that inanimate models cannot replace animals in trauma training. It only implies that such a replacement would be inappropriate in a training event that has as its goal the development of autonomy or terminal performance proficiency in these procedures. The question of replacement is answered by defining the training objectives of the event, and by considering other practical concerns such as model availability and the impact of using multiple models during one training event. Course directors may not have access to models that enable them to replace animal use in their laboratories. If patient assessment is a goal, the lab will require the use of animals or CIMs. The fact that CIMs cost $200,000, and that there are currently only 50 being used nationwide, is a limiting consideration. Additionally, the use of multiple models in a single training event may be such a distraction to the students that their use is educationally impractical. Hence, the identification of replacement alternatives is not always a prescription to replace a given animal use. Simply satisfying a given training event's unique Event-Totality Standard will not always lead to replacement, despite the fact that such a replacement is the goal.

Summary

In order to determine the ability of inanimate models to replace animals in trauma procedure laboratories, evidence was collected and analyzed using niche analysis and an Event-Totality Standard. During niche analysis, models were categorized then evaluated to determine characteristics, which would define their appropriate role in psychomotor skill development. This role, their niche, was used as the basis of comparison against animal models. An alternative, which can fill the niche of animal models in trauma training, can replace that animal use. Additionally, an Event-Totality Standard, comprising critical resuscitative procedures, was applied to determine if identified models could replace the use of animals in trauma training. If

each procedure in the ETS can be trained using models to the same standards as it is trained using animals, then the animal use can be replaced.

Niche analysis indicates that NPMs are appropriate only for cognitive skill development. NRPMs, AAMs, and CADs are most appropriate for integrative level skill development because their availability encourages repeated basic skill practice. Additionally, they do not offer characteristics such as feedback and clinical realism, which allow them to be used at the autonomous level of psychomotor development. Only animal models and CIMs are appropriate for autonomous level skill development or terminal proficiency testing. CIMs allow advanced patient assessment and decision making, but they are designed for use by anesthetists. They lack certain elements of procedural realism that might allow them to be used more extensively in trauma training. They are also expensive and rare. Animal models offer characteristics that make them ideal not only for autonomous level training, but also for terminal performance proficiency testing.

An Event-Totality Standard comprising critical resuscitative procedures was applied to determine the individual or collective ability of identified inanimate models to replace animals in trauma training. No single alternative can replace the use of animals in trauma training. On superficial analysis, alternative models may collectively fulfill the ETS; however, they do not allow the same level of training to be conducted on each procedure as if it were performed on an animal model. Application of niche analysis to the first, superficial, ETS analysis demonstrates that for many procedures, models can be used to train medics to the same level of proficiency as can animals. However, certain critical procedures cannot be performed to an acceptable standard using inanimate model. Among these patient assessment and stabilization, peritoneal lavage, pericardiocentesis, venous cutdown, and hemorrhage control.

Using these criteria, inanimate models cannot currently replace the use of animals in trauma training. Given different training objectives and a different list of required training

procedures, inanimate models may be able to fulfill the ETS and completely replace animal use in that trauma-training event. However, identification of a set of inanimate models which might replace animal use in a given event does not guarantee that all the necessary models will be available, or that the use of a given set of models will not be so cumbersome as to detract from the training event.

CHAPTER 5

DISCUSSION

Introduction

Trauma training is regularly conducted within both the civilian and military medical communities in an environment of increasing scrutiny and pressure from the public and governmental agencies to replace animals with inanimate alternatives. This thesis used the Advanced Trauma Life Support (ATLS) animal laboratory as the basis of evaluation to answer the question: Can nonanimal alternatives replace the use of animals in military medical trauma training?

Evidence was collected via a literature review referencing the topics of animate and inanimate model use in surgical and trauma training. Procedural psychomotor skill development theory was also reviewed in order to establish the basis for evaluation of the identified models. Most of the literature recovered came from professional medical journals. There were no prospective studies comparing the use of animate and inanimate models in trauma training. Nearly five hundred articles were reviewed during the evidence collection process. Only fourteen journal articles directly discussed the topic of model use in resuscitative procedure laboratories. Other medical training literature was reviewed to gain evidence leading towards the classification and evaluation of identified models. The bulk of the articles reviewed were descriptive in nature.

Evidence was evaluated using niche analysis and an Event-Totality Standard. Identified models were categorized (NPM, NRPM, AAM, CAD, and CIM), and analyzed to determine characteristics which would identify their optimal role in psychomotor development--their niche. Any model which might fill the same niche as animals in trauma training could replace that animal use. Additionally, an Event-Totality Standard, comprising critical resuscitative procedures, was used to determining if the identified models might, individually or collectively, replace the use of animals in trauma training. A model or group of models, which might satisfy

the ETS, without any loss of training value for the student could replace the use of animals in trauma training.

Conclusions

Ultimately, inanimate models can only replace animals in trauma training if they allow the attainment of a comparable level of proficiency for the given student population, level of training, and educational objectives. The current evidence suggests that inanimate models cannot replace the use of animals in trauma training.

Niche analysis determined that NPMs are well suited for use during the cognitive level of psychomotor skill development; however, they do not develop manual skills. Subsequently, they were not considered as alternatives to animal use in trauma training in this thesis. NRPMs, AAMs, and CADs are most appropriate for the development of basic psychomotor skills at the integrative level of psychomotor development. The characteristics of these models encourage repeated practice of basic skills, but do not allow for use in the autonomous phase of development. CIMs and animal models are both well suited for the autonomous level of psychomotor development. However, since CIMs are designed for anesthetist training, they are not well suited for the performance of resuscitative procedures. CIM manufacturers have noted this shortfall and are beginning to incorporate trauma training modifications and computer simulations. Additionally, CIMs are prohibitively expensive. Animals are not only ideal training models at the autonomous level of psychomotor development, they are also excellent testing models for terminal performance certification.

Application of the Event-Totality Standard was used to determine if the identified models could individually or collectively replace the use of animals in trauma training. On superficial examination, inanimate models can be used to train each of the ETS procedures. Many, but not all, of the ETS procedures could be trained with inanimate models at the same level of

psychomotor development as could be attained using animals. Significantly, patient assessment and stabilization, venous cutdown, and hemorrhage control could not be trained at a comparable level. Thus, the identified inanimate models were unable to satisfy the Event-Totality Standard when niche analysis was concurrently applied to ensure comparable student learning experiences.

Ultimately, the question of whether inanimate models can replace animals in trauma training depends on three variables unique to each animal facilitated trauma training event: (1) the student population, (2) the availability of inanimate models, and (3) the educational objectives of the event. The educational objectives, which are linked to the student population, determine the level of psychomotor development that needs to be achieved. At a lower level of development the identified set of models might have satisfied the ETS. Even so, the ability of inanimate models to replace the use of animals in trauma training is subject to practical considerations. Some models are not available or are simply to expensive to use in a given training program. Additionally, some combinations of models, which might otherwise satisfy the ETS, may be so cumbersome to use that they detract from the training event. The goal is not to use one model or another, or to replace one model with another. The goal is to train confident and competent first responders. This goal is achieved by using the models, which best match the unique needs of each different training program.

Research Design Strengths and Weaknesses

This study identified, and categorized animate and inanimate models being used in psychomotor skills training. Models were analyzed for characteristics that suggested beneficial use at a given level of skill development. Models were also applied collectively to the Event-Totality Standard to determine their ability to replace animal modela in the trauma-training laboratory. The limitations of this study were introduced in chapter 1. Lack of objective data required a content analysis and comparative methodology. As a ‘review of reviews’ this study

was limited to subjective analysis of the data presented. An encouraging aspect of evidence collection was that authors offered both criticisms and benefits in their model discussions. Frequently, the authors offering elaborate discussions of advantages also offered numerous disadvantages as well.

In his trauma model study, Bruce Pince (1980) applied a semi-quantitative rating to trauma models. In this thesis, no attempt was made to similarly rate identified models since such an evaluation would be subjectively based on the author's experience. In essence, this is no better than the interviews or surveys, which were excluded from this study as an evidence source. However, the chosen methodology was designed to eliminate, as much as possible, such subjectivity. Alternate models were identified and analyzed, then recommendations made. The logical deduction of conclusions based on the evidence presented, while not objective, has minimized subjectivity. Nevertheless, this thesis offers suggestions rather than objective conclusions, such suggestions are subject to the reader's own evaluation and implementation.

The Boilerplate

As part of the consideration of this topic, a boilerplate argument must be offered. Anecdotally, it has been the author's experience that the most commonly articulated advantage of performing resuscitative procedures on live animals is that this one training event defined the student's acceptance that he, personally, was prepared to "cut" another living human being. Neither model nor cadaver use prior the animal facilitated training event instilled this level of confidence. Dr. Albert Bandura (1981), a noted behavioral psychologist, has forwarded the theory of "efficacy expectation," which states that confidence is a variable in proper task performance.

The effect that animal use in a training event is able to instill a higher level of confidence than can be achieved by training on inanimate models is noted in the literature. However, this higher level of confidence is not observed after the first live performance of the required

procedure. Karl K. White and others (1992, 9) noted that "students from the alternative surgical laboratory program [were] more timid and hesitant the first time they incise[d] living tissue. This hesitance [was] only apparent on the first live tissue surgery." This same observation was noted by Dr. Cathy Greenfield and others (1995, 1842): "students who had previously worked on models were somewhat more anxious than other [traditionally trained] students at the beginning of these sessions, were more tentative when making initial incision, and were more nervous when they first encountered bleeding vessels."

The fact that lack of confidence will negatively affect first time performance was noted by Ovassapian and others (1983, 796-7), who attributed a high incidence of intubation procedural difficulty to a reluctance on the part of clinicians to perform procedures that they were not confident with. He also noted that "students, [who] felt comfortable, even on their first intubation attempt," achieved a higher rate of procedural success than those who did not. He rated self-confidence as an essential attribute of successful initial performance.

If the assumption that resuscitation demands first time, independent, proficient performance from the medic is accepted. Further, if the educational philosophy that confidence is a training goal during the autonomous phase of skill development, and is required for first time performance of resuscitative skills, is accepted. Then the logical conclusion follows that one cannot expect unhesitating action in the stabilization and treatment of combat casualties without the validation step of performing live animal trauma labs. The evidence suggests that medic performance will be significantly better only during treatment of the first casualty. The "boilerplate" question becomes: Is the hesitance borne of first encountering a living trauma patient, which might cost the life or limb of a soldier, worth the life of an animal? This is a personal question that can not be answered by this thesis.

The fact that failures of medical preparedness cost lives is an accepted and historically supported fact. At the beginning of the American Civil War, anesthesia and surgery were new

disciplines. Only a handful of the physicians had experience in the stabilization and treatment of battlefield casualties. By the end of the war, the Union medical service had enlisted over 15,000 military surgeons. The "training" of this 15,000 to perform resuscitative techniques was clumsy, meddling, trial and error on wounded soldiers. Battlefield surgeons learned quickly, but the cost of this "training" was soldiers' lives. Medicine has changed; techniques have changed; training methods have changed. The fact that lives lie on the balance has not changed--animal lives on the one side and human lives on the other. The conclusions of his thesis can not tip this scale.

Recommendations for Further Study

This study has addressed the issue of animal use in trauma training. Its scope was narrowly defined to include the role of animate and inanimate models in the initial development of trauma skills in first responders. The investigation of this subject has uncovered many questions that lay beyond the scope of this thesis, yet are worthy of investigation. In truth, the justification of animal use in trauma training still hinges on the resolution of such questions and the subsequent implementation of the recommendations delivered by their examination. The following questions are offered for further investigation:

1. What procedures should be taught in trauma training? There are commonly performed procedures in trauma skill laboratories. This thesis used such a set of procedures as the ETS. This question has never been researched fully using such variables as the difficulty of a skill to train, the level of invasiveness, the probable outcome of treatment, the severity of complications due to improper performance of skill, or the morbidity and mortality if a patient needing the treatment does not receive it.

2. What are the prerequisite skills before a student should be allowed access to animal facilitated training? This thesis introduced the idea that animal models are inappropriate for basic

skill development. How can the point at which the leap from inanimate to animate models is indicated be recognized?

3. Is there an appropriate sustainment interval for trauma training? What is the rate of cognitive and psychomotor skill attrition? Work is being conducted in this area. If the sustainment interval can legitimately increased, the total number of animals used can be reduced.

4. What is the impact of animal facilitated trauma training on groups or teams? Should team training using animals be conducting? There is evidence that such training might be beneficial (Smeak et al. 1991).

Summary

The goal of trauma training is to develop healthcare providers who are capable of functioning competently, confidently, and independently in the face of battlefield trauma. This goal will not be easily achieved. The attainment of this goal should be independent of means and not limited by subjective opinions about the training benefit of one model over another. Animal use in training is meeting increased scrutiny, which can result in educators taking a defensive posture over their current instructional methods. Taking the defensive leads to reactivity and resistance rather than proactivity (Chambers 1986). Misunderstanding the alternatives concept, believing that alternatives mean only replacement, and fearing that the use of one alternative may domino into the replacement of all animal use experiences, leads many trainers to see only the threat and not the opportunities of using alternatives in trauma training. The presence of such apprehension over the limited replacement of animal use with alternative methods is documented (Greenfield et al. 1994). Trauma trainers must not be caught in this trap; they must base their decisions on analysis using more objective criteria. Educators should not be concerned with the advocacy of the use or disuse of animate or inanimate models in training, but rather they must be concerned with advocating the most appropriate use of the models at their disposal. The use of

appropriate animate and inanimate models during trauma training derives the greatest benefit for the student. The models best suited for basic psychomotor skill development are not well suited for advanced skills training and proficiency certification. Models best suited for autonomous development are not well suited for the integrative level. Animate and inanimate models each have their own niches in training emergency care providers. This analysis has concluded that inanimate models could not currently replace the use of animals in trauma training. In a different environment, requiring different skills, performed by different students, a similar analysis might offer different conclusions.

APPENDIX A

THE ALTERNATIVE CONCEPT

The concept of alternatives was introduced in 1959 by the British scientists William Russell and Rex Burch, who offered humane treatment techniques as the 3Rs: Replacement of animals with nonanimal models; Reduction of the numbers of animals used; and Refinement of methods in order to reduce animal pain and distress (Kreger et al. 1998; and Russell and Burch 1959). The concept of alternatives is much broader in scope than the absolute replacement of an animal with a nonanimal model and is applicable to any technique that might improve the animal use or the benefit derived from it. The goal of the 3Rs is the elimination of avoidable animal pain, and while not all animal uses may be replaced, all should be examined for possible improvement. While the techniques employed have changed over the years, the application of Russell and Burch's basic tenets has withstood the test of time.

Replaceme\nt. Replacement implies the substitution of insentient materials, or phylogenically lower animals that are less sensitive to pain and distress, for a given animal use, thereby eliminating the use. B. Taylor Bennett and others (1994) discuss replacement in the following broad categories: Use of Living Systems, Use of Nonliving Systems, and Use of Computer Simulation.

While the potential of nonvertebrate living-system alternatives is limitless, they are not applicable to trauma training. Common living system (in vitro) techniques include organ, tissue, and cell cultures, and are replacing live animals in microbiological, toxicological, and pharmacological research. The use of living invertebrate animals, microbial cultures, and plants is also increasing.

The use of nonliving systems (chemical techniques or physical systems) is more applicable for training trauma skills. While chemical techniques such as improved immunoassays are of little application, improved physical systems (models) offer great replacement potential.

The use of mannequins, realistic models, and cadavers is finding increased success as the development and application of these models improves. Under limited circumstances, the use of mannequins and cadavers has completely replaced the use of live animals during the conduct of ATLS practicums (PCRM 1999).

The use of computer simulation must also be considered. The use of computer simulation has almost completely replaced the use of live animal models in medical school physiology laboratories (PCRM 1999). Many corporations are developing computer software, interactive programs, and virtual reality simulations for trauma training scenarios. Army medical training directives called for the integration of virtual reality and computer simulation technologies into trauma training programs as early as fiscal year 1996 (DOD 1995). The DOD is heavily involved in the sponsorship and evaluation of these products.[1]

Reduction. Reduction implies decreasing the absolute number of animals used to gain information of a given amount or precision within an institution's animal use program or within a specific project. Reduction is applicable to individual projects as well as being an important measure of institutional animal use programs as a whole. The absolute reduction in numbers of animals used must always be the ultimate goal of any program. Bennett and others (1994) discuss reduction on terms of the following broad categories: Animal Sharing, Improved Statistical Design, Phylogenetic Reduction, and Better Quality Animals.

Animal sharing emphasizes gaining the maximum benefit from each individual animal. This can involve sharing animals for data collection across experiments or mean increasing the number of students training on any given animal. Obviously, training many students with the same animal decreases the number of animals required. The task of balancing a high student : animal ratio with decreasing training value at higher ratios is challenging.[2] The America College of Surgeons requires no more than four students per surgical station during its ATLS practicum (ACS 1997). Most believe that no further reduction in the current animal to student ratio is

reasonable before training quality is seriously deteriorated and the overall value of using animals becomes questionable.

Improved statistical design involves analysis to determine the lowest number of animals required to meet data collection requirements while retaining significance of results in experimental designs. It is not applicable to trauma training uses. Neither is phylogenetic reduction (substitution of lower order animals for more sentient ones) applicable since a mammalian model is required in the training of resuscitative and surgical skills applicable to human patients.

Better quality animals implies the reduction of animals achieved when techniques such as genetic engineering and transgenic animal production, or the identification of experimental and control groups best suited to a protocol, can be employed to offer animals with specifically needed characteristics. These techniques are of little value in animal facilitated trauma training; however, proper model selection and the use of conditioned animals has shown benefit in the conduct of animal labs (Sternbach and Rosen 1977). Such animals are more likely to survive throughout the training laboratory.

Refinement. Refinement is defined as activities that reduce the pain and distress suffered by the laboratory animals that are used. Protocol refinements, being concerned with improvements aimed at humane treatment issues, are the most neglected alternative aspect because they are less tangible. Hence, a refinement such as the use of a new anesthetic agent will produce few benefits in terms of animal number reduction or replacement, but will have tremendous impact on the alleviation of pain in individual animals involved in the protocol. Additionally, their discovery is difficult since databases are not designed for their easy retrieval, and refinements are usually specifically related to the proposed animal use. Conversely, refinements that improve a training event in which animals are used may have substantial impact that results in reduced numbers of animals being used. As will be discussed below, collective

refinements such as better-prepared students, animal sharing, and use of human medical instruments will lead to more efficient use of animal models (reduction). Bennett and others (1994) discuss “refinement” in the following broad categories: Decreased Invasiveness, Improved Instrumentation, Improved Control of Pain, and Improved Control of Techniques.

Decreased invasiveness implies conducting procedures that produce less tissue destruction and pain. Surgical procedures are divided into major and minor procedures based on invasiveness. Major surgeries can be expected to produce major physical or physiological impairment, and include laparotomy, thoracotomy, and amputation. Minor procedures are less invasive, including surgeries routinely performed on an outpatient basis in clinical practice. Obviously, a simple incision is less invasive than an open cavity wound, and would be expected to produce less pain. Survival following a major surgical procedure is discouraged because of the expectation of pain and distress in the postoperative period (NRC 1996, 60-64). For this reason, most trauma training evolutions are terminal events for the animals involved.

Improved instrumentation involves techniques that improve animal monitoring, data collection, and biologic sample analysis. Telemetry has greatly improved sample and data collection by providing a constant data stream and eliminating data adulteration due to animal responses during handling. In animal facilitated trauma training, appropriate instrumentation is critical to ensure the maximal transfer of skills from the animal use experience to use on human patients. All instrumentation used for training procedures and patient monitoring should be performed with human medical equipment so that lessons learned are directly transferable to human patients.

Improved control of pain implies the use of anesthetic agents that have scholarly literature validating their anesthetic and analgesic properties in the species used. The application of multi-modal balanced anesthesia protocols, to include preemptive analgesia, offers significant pain control improvement in laboratory animals.

Improved control of techniques is achieved by ensuring that all personnel involved in the event are adequately trained and that animal handling techniques are designed to minimize animal distress. The minimization of animal distress can be addressed at the institutional program level through improvement of caretaker training, facilities, animal handling, restraint, preparation, and husbandry. At the protocol level, control of techniques implies the guarantee that individuals performing procedures on animals are appropriately trained.[3] Medical professionals usually provide instruction, supervision, and procedural oversight during trauma labs. In the ATLS practicum, an ACS certified surgeon-instructor oversees the training of each four-student group (ACS 1997).

Responsibility. The fourth R (Responsibility) is not found in Russell and Burch's trinity (3Rs), but is found in DOD policy and AWIC publications. Responsibility implies stewardship of the animals under our care. We are institutionally and personally responsible for the animals entrusted into our care. We are responsible for provision of the best possible care, resulting in the least stress on the animals. Military medical professionals are also responsible to the public for appropriate stewardship of resources and the commitment to saving lives. Fortunately, most medical healthcare providers are experienced professionals who do not tolerate breeches in ethics or protocols. Aggressive development and promotion of the other 3Rs in the planning and implementation of research is the hallmark of the fourth: Responsibility (Bennett et al. 1994). Table 19 offers examples of the application of alternative methods to trauma training.

TABLE 19
ALTERNATIVES USED IN TRAUMA TRAINING

Alternative Category	Trauma Training Application
Replacement	
Use of Living Systems	N/A
Use of NonLiving Systems	NRPM, CAD, CIM, and AAM use
Use of Computer Simulation	NPM (CS, IVD, VR) use
Reduction	
Animal Sharing	Appropriate Student : Animal Ratio
Improved Statistical Design	N/A
Phylogenic Reduction	N/A
Better Quality Animals	Conditioned animal use
Refinement	
Decreased Invasiveness	Procedure selection / Euthansia
Improved Instrumentation	Human medical instrument use
Improved Control of Pain	Modern anesthetic agent use
	Multi-modal and pre-emptive anesthesia techniques
Improved Control of Techniques	Professional oversight
	Preparation of students

The alternatives concept has seen increasing acceptance and application over the past half century. Since 1985, Congress has required investigators to provide assurances that they have sought alternatives to painful procedures performed on animals in order to fix the responsibility for reducing animal pain and suffering in experimental animal use (AWA 1985). The "classic error [is] defining the term [alternatives] as the three R's and then thinking only in terms of the one R, replacement" (Rowan 1991). This is the major criticism of animal rights organizations' approach to insistence on alternatives in animal use. While the replacement of a given animal use may be inappropriate without degradation of the training event, opportunities for reduction and refinement are often found. Aside from the ethical responsibility of conducting the alternative search, it is beneficial in disclosing unnecessary duplication of effort,[4] precluding the unnecessary

use of animals, and in terms of economic benefits. The animal use approval process helps to ensure that this search is made and responsibility is fixed.

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1. More examples of such involvement are found on the DTIC database. Internet. Available from http:// dticam.dtic.mil.

2. While this topic is relevant, it will not be discussed in this paper. It does, however, pose a fitting question for students of both laboratory animal medicine and adult education. Jameel Ali and other ACS trauma committee members have explored the topic.

3. This is another relevant topic that will not be discussed in this paper. The determination of what qualifies a student to derive maximum, or even acceptable, benefit from an animal facilitated training event is worthy of research.

4. Reproducible results are a tenet of empirical discovery. The mandate to avoid unnecessary duplication does not preclude this endeavor, but prevents unintentional duplication.

APPENDIX B

THE ETHICAL DEBATE ABOUT ANIMAL USE

Humans and animals have coexisted and had defined relationships since pre-historic times[1]. These relationships included food, fiber, labor, and companionship. The domestication of animals, and the harnessing of animal labor for cultivation, was one of the stepping stones upon which civilization was founded. Over the years, husbandry methods have changed greatly, but the relationships have changed little, except for the addition of the relationship of research use. This relationship is a focal point for the ethical debate concerning animal use that has developed in the past several decades.

The dominant concept defining this relationship today is Animal Welfare (AW).[2] The term welfare can be simply defined as health and well being, with implications of freedom from disease or discomfort. Further, it moves beyond healthcare alone to the application of measures directed at influencing the whole animal: its physiological, psychological, and behavioral well-being (Albright 1997, 5). AW is an acceptance of the responsibility to provide for the welfare of the animals under our care. This has implications beyond the realm of laboratory animal care. AW necessitates measures affecting health, socialization, handling, and husbandry, arriving at an optimal state of being for all domesticated animals. The stockman interprets this optimal state to mean docile behavior, musculoskeletal and reproductive soundness, and freedom from disease, while the laboratory animal technician interprets this to mean healthy, stress free animals capable of producing significant data sets. The different interpretations are not important; the endstate is. The stewardship that arises from the responsibility for the welfare of animals under our care encourages high standards that to the stockman derive increased productivity and for the investigator create better data sets for evaluation. In both cases the benefits are attained through proactive, rather than reactive, programs. AW is the ethical standard that influences all human-animal relationships today.

AW assumes the inherent superiority of man over other animals, and hence his ability to use them for benefit. However, it also assumes responsible stewardship of the animals under Man's care. The public agrees that animal research is necessary; 75 percent accept the practice (Rowan 1991). The American people willingly support the use of animals in research and medicine when there is a direct benefit for humans and no apparent distress is caused to the animal. AW is consistent with deep seated cultural values such as the Principle of Beneficence ("Golden Rule"). Further, institutional disregard for these ethical concerns has resulted in negative psychological impact (withdrawal, conflict with authority figures, callousness and indifference, decreased work performance, absenteeism, alcohol or drug abuse) in laboratory animal caretakers (PHS 1996; and Arluke 1999). AW is essential not only in an ethical sense, but also in a practical sense, to those who deal with animals on a daily basis in the laboratory setting. It is the foundation of the current standards for animal care and use. All animal use oversight organizational standards (AAALAC, PHS, ACLAM) and legislation is based on the concept of AW.

Another ethical concept that has had tremendous impact on the attitudes towards and regulation governing animal use is Animal Rights (AR).[2] AR advocates refute "speciesism"[3] noting that animals have rights equal to those of humans (Singer 1990). The most significant discourse on animal rights, Tom Regan's *The Case for Animal Rights*, argues equal rights for animals based on demonstrated perception, desire, memory, self-consciousness, and capacity to experience pleasure and pain--all qualities of sentience and individual identity (1983, 81). The use of animals as pets, as livestock, for labor or pleasure, or for research is considered inappropriate. While AR advocates differ in degree of commitment, "animal rights doctrine is essentially philosophical, anti-vivisectionist, vegetarian, pro-activist, [and] moralistic" (Albright 1997, 6). AR doctrine is an inflexible call for the animal to be given freedom: of choice, of movement, of thought, of rights, of interest, and of identity. Despite this inflexibility, the Rights

movement's impact must be acknowledged. In 1998, PETA, the world's largest AR organization, had over 780,000 members, had a budget of over $13 million, visited over 70,000 school classes, and distributed over 22 million humane treatment kits to students (PETA n.d.d). The AR movement has had tremendous exposure and opportunity to effect ethical mores governing animal use.

It is important to differentiate the two posturing philosophies. AW reflects responsible concern for the humane treatment of animals, while AR holds that animals should not be exploited in any manner. While animal rights proponents may forward advocacy of animal welfare issues, there is always an underlying animal rights agenda (Albright 1997, 6). Tom Regan argues that "human and animal welfare do not differ" (1983, 116). While AR supporters may advocate the necessity of alternatives, they call for replacement, forgetting the other 2 Rs (reduction and refinement).

> The rights view will not be satisfied with anything less than the total dissolution of the animal industry as we know it. . . . In general, the rights view's position is to let the wildlife be. . . . All that the rights view prohibits are procedures that violate the rights of individuals. It is not reduction of the number of animals that is required, or refinement of one's protocol. The rights view calls for the total elimination of the use of animals. . . . The rights view abhors the harmful use of animals in research and calls for its total elimination. (Regan 1983, 395-7)

When AR and AW meet, ultimately "the debate over how best to promote animal welfare shifts to the [intended] debate on animal rights versus human rights" (Mathis 1991, 4). As unsupportable as these views may seem, the AR movement can claim "the closure of a military laboratory in which animals were shot, and stopping the use of cats and dogs in all wound laboratories. *US Magazine* reports, 'PETA has had an enormous effect on the way corporations treat animals.' . . . Investigative work, congressional involvement, consumer boycotts, and international media coverage frequently result in improvements in the quality of life for, and saves the lives of, thousands of animals. According to *The Washington Post*, because of PETA, 'labs have closed. . . . Rules, laws have changed'" (PETA n.d.a). It is important to differentiate

the two stances. It is important to understand that AW is a commonly accepted responsibility, while AR is an individual philosophical tenet. It is also important to remember that both have affected, and continue to effect, public attitudes and animal use regulation.

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1. Now the Lord God had formed out of the ground all the beasts of the field and all the birds of the air. He brought them to the man to see what he would name them; and whatever the man called each living creature, that was its name. So the man gave names to all the livestock, the birds of the air and the beasts of the field . . . (Genesis 2:19-20 NIV) and [God] let them [Man] rule over the livestock, over the earth, and over all the creatures that move over the ground (Genesis 1:26 NIV).

2. In this discussion, the abbreviations AW (Animal Welfare) and AR (Animal Rights) are used to identify the conceptual ideologies and to distinguish them from the common usage of the terms "welfare" and "rights" as applied to animals.

3. Peter Singer (1990, 6) coined the term "speciesism"--"a prejudice or attitude of bias in favor of the interests of members of one's own species against the those of the members of other species"-- as an analogy to "racism" or "sexism." Animal Rights advocates deny that Man is inherently superior to other species and thus have no right to dominate other species or use them for human ends.

APPENDIX C

THE ANIMAL USE APPROVAL PROCESS

Introduction

The ethical concerns governing animal use are acknowledged in both regulatory measures and the practical measures employed by institutions that use animals in research, development, testing, and evaluation. Animal use is far from indiscriminate and any proposed animal uses undergo lengthy consideration before it occurs. This appendix offers a basic review of the animal use approval process outlining animal use regulation, animal use protocols, and the protocol approval process.

Applicable Regulation

Concern about the ethical treatment of animals and animal use legislation is not new. Historical examples include the Puritan's "Body of Liberties" (Massachusetts, 1641), the "Anti-Cruelty Law" (New York, 1828), and the Federal "28 Hour Law" (1873) (Kreger et al. 1998, and AWIC 1997). While these laws were based more on survival, economic, and religious motives than ethical concerns, they illustrate that concern for animal welfare is not a recent phenomenon. Modern animal use regulation has been designed to ensure that laboratory animal care and use is consistent with current ethical mores. This regulation falls into the classifications of public law, agency policy, and institutional regulations.

The Animal Welfare Act, 7 U.S. Code 2131-2158 (24 August 1966) and its amendments (1970, 1976, 1985, and 1990) as implemented by USDA Regulations 9 CFR Parts 1-4 are the basis of animal use legislation in the United States. The AWA's original implementation (Public Law 89-544) legally defined the status of animals and granted the Secretary of Agriculture authority to effect regulations directed at the protection of pet animals and the provision of humane care for laboratory animals. The 1970 amendment (PL 91-579) ensured humane

treatment of animals used in research or exhibition by regulating transportation, sale, housing, care, handling, and treatment of animals in commerce, exhibition, and experimentation. The next amendment (The Animal Welfare Act of 1976, PL 94-279) regulated animal transport by modern commercial carriers (air, bus, truck), provided for heath certificates prior to transport, provided for licensing and penalties, and outlawed exhibition of fighting animals (dogs). The most significant legislation governing laboratory animal care was enacted in 1985 to include the Food Security Act of 1985 (PL 99-198) (with attached amendment: the Improved Standards for Laboratory Animals Act) and the Health Research Extension Act of 1985 (42 U.S.C. 289d). These amendments define "humane care" to include sanitation, ventilation, and housing, direct enrichment activities,[1] and mandate the minimization of pain and distress through adequate veterinary care, anesthesia, analgesia, tranquilizers, and euthanasia. This amendment prescribes IACUCs, alternative search, and protocol approval. It also prescribes the formation of AWIC and other agencies involved in animal use oversight. Finally, the Food, Agriculture, Conservation, & Trade Act of 1990 (PL 101-624) (also called the Pet Protection Act) addresses pet animal sales and transport, and implements measures for AWA enforcement. Again, the single source compilation of legislation governing animal use is 9 CFR Parts 1-4. Current legislation reflects AW as the dominant ethical concept influencing animal use.

Public Health Service (PHS) policy regulates all animal-use institutions in which research is funded by government grant or subsidy.[2] PHS policy is found in publications including the *Public Health Service Policy on the Humane Care and Use of Laboratory Animals*, the *Guide for the Care and Use of Laboratory Animals*, and the *Institutional Administrator's Manual for Laboratory Animal Care & Use*. These policies are a reflection of AW concepts and current legislation governing animal-use. They prescribe institutional programs, IACUCs, and veterinary care. PHS policy also provides for inspection and the award of an institutional status; only institutions maintaining, or actively pursuing, accredited status may receive government research

funding. PHS policies tend to be performance-based rather than criteria-based. They outline expected end states that are consistent with animal welfare, rather than offering checklists that might limit caretaker initiative. They call for investigators to make assurances (to their institutions, the government, and the public) of good faith efforts taken to provide for the welfare of the animals under their stewardship.

Army regulation[3] of animal use is found in DoD Directive 3216.1 (The Use of Laboratory Animals in DoD Programs) and AR 70-18 (The Use of Animals in DoD Programs). DOD institutional regulations prescribe animal acquisition requirements, species limitations (dog, cat, and primate), and standard protocol format. They apply a "most stringent standard"[4] rule to the above mentioned governmental regulations. They attempt to add qualitatively, not quantitatively, to the existing regulations. While the AWA prescribes the role of an IACUC of three persons, and PHS policy calls for five, the Army regulation also designates the types of members (scientific, nonscientific, nonaffiliated, veterinarian, scientist). They prescribe AAALAC accreditation for all DOD animal use activities. Finally, they fix responsibility on the commander for both the animal use conducted within his institution and that out-contracted by his institution.

Oversight of institutional animal care and use activities is conducted at the institutional, government agency, and private organization level. The most widely recognized oversight assurance offered by animal use activities is full accreditation by the Association for Assessment and Accreditation of Laboratory Animal Care-International (AAALAC), a private nonprofit organization. AAALAC accreditation is referenced as the expected standard of animal welfare excellence in both Army regulation and PHS policy. AAALAC conducts an inspection program of announced and unannounced visits, together with regular reports and institutional program reviews, arriving at an accreditation status. AAALAC certification of DOD animal use facilities has been a requirement since 1996 (GAO 1999, 12). AAALAC accreditation provides the

institution with universally accepted third party corroboration to its assurances of animal welfare within its animal use program.

Animal Use Protocols

Before any animal is used in research, development, testing, or evaluation (RDTE), the proposed use must go through an extensive approval process to ensure that the animal use is consistent with all applicable legal and ethical considerations. The principle investigator must prepare a detailed description and justification of the proposed animal use called a protocol. In 1996, the DOD implemented the use of a Standard Protocol Format (GAO 1999, 12):

> The standard [DOD] protocol format requires that investigators address several elements, including the study background, objectives and hypotheses, military relevance, experimental design, animal requirements and justifications, research procedures, veterinary care, investigator qualifications, and safety issues. In the protocols, investigators are required to provide written assurance that the proposed research does not unnecessarily duplicate other studies. This requirement stems from animal welfare regulations. In addition, DOD requires that its investigators review specific electronic databases to identify whether the proposed research could unnecessarily duplicate other studies; document the results of their search; and identify the databases searched, key words used, and the dates of the search. Investigators must present written justification for the use of animals, to include consideration of nonanimal alternatives, the total number and species of animals to be used, and alternatives being employed. (GAO 1999, 29)

The animal use protocol serves as documentation of the principle investigator's topical research efforts, justification of his need to use animals, and "blueprint" for the conduct of the experiment. It is his good faith assurance of responsibility for the welfare of animals under his care. The approved protocol becomes a contract between the IACUC, providing legitimacy to and oversight of the event, and the investigator, legally and ethically conducting the event. All uses of laboratory animals must be conducted under an approved protocol. Figure 3 graphically depicts the DOD's animal use approval process.

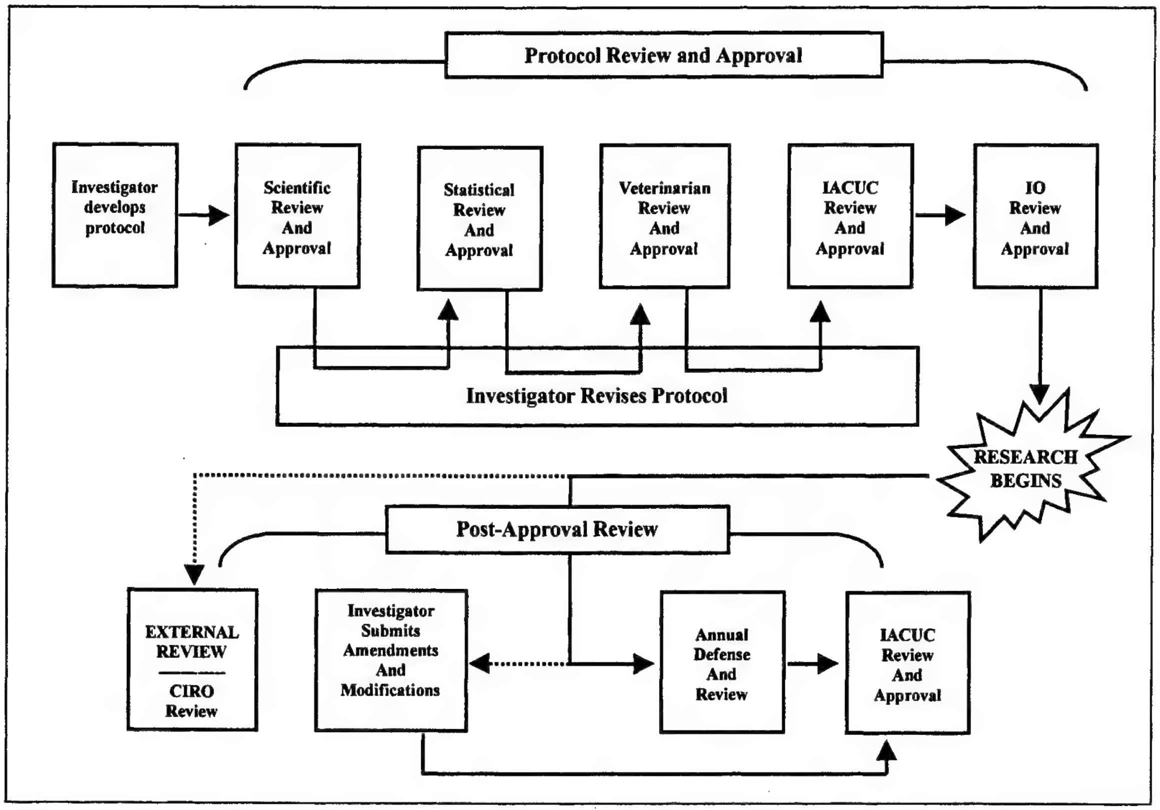

Figure 3. DOD Animal Use Approval Process. While minor variations exist, this figure is consistent with the protocol approval process followed by DOD animal use activities (GAO 1999, 28). Specific review policy is found in the given activity's Animal Care and Use Program.

Protocol Approval

Most institutions, to include the Army, have an extensive animal use protocol review and approval process. The approval process prescribes multiple review steps in order to reduce unnecessary duplication of effort, promote alternative use, ensure scientific merit, and ensure ethical and legal adherence. An in-house scientist conducts the scientific merit review focusing on the proposed protocol's justification of animal species used, search to avoid unnecessary duplication of effort, application of data collection techniques and technologies, and justification of the project's contribution to the advancement of scientific knowledge (scientific merit) and military objectives. Most commonly, the investigator uses databases such as MEDLINE[5] to research these aspects of the project; the reviewer may choose to conduct similar searches or

simply review the material presented within the protocol. The DOD standard protocol format requires methodology review by a trained biostatistician to ensure that the use of animals is minimized, and that statistical assumptions and experimental design are appropriate. The attending veterinarian, an individual trained or certified in laboratory animal medicine, reviews the protocol to ensure its adherence to DOD policies, the use of appropriate surgical anesthetics and husbandry techniques, and the minimization of pain and distress. These reviews may be conducted sequentially or concurrently; institutions may use a scientific subcommittee (of the IACUC) in order to conduct these reviews more efficiently. Additionally, the attending veterinarian and biostatistician have usually already been consulted by the investigator during the protocol development process.

Having passed these technical reviews, the investigator presents and defends his protocol before the assembled IACUC, which reexamines the protocol for considerations investigated during the technical reviews. It may choose to receive a report from the scientific subcommittee and review the investigator's application of the recommendations made by the committee. Since 1995, in order to avoid unnecessary duplication of efforts, DOD has required a search for and mention of similar animal uses on, at a minimum, the Defense Technical Information Center (DTIC)[6] and the Federal Research in Progress (FEDRIP) databases (GAO 1999, 11). Documentation of a search for and the consideration of alternatives to painful procedures has been required since 1996 (GAO 1999, 12). The IACUC must conduct similar searches or review those provided by the investigator. Further, the IACUC review is designed to ensure that the proposed animal use is consistent with legal and ethical considerations. The IACUC requires the investigator to make assurances of good faith efforts to provide for animal welfare. The IACUC may approve the protocol or make further recommendations for improvement. The approved protocol is recommended to the IO for final approval. Protocols return to the IACUC for annual review and defense, and for approval of amendments or modifications.

The IO reviews the protocol as its final approving authority. He is most concerned with the specific project's adherence to institutional policy and its applicability to the institution's overall research goals. He may prescribe, at this point or previously, a funding review of the project. He has veto authority over any protocol recommended by the IACUC, but cannot approve one without their recommendation. The IO confers tacit approval of a protocol when he returns the minutes of the IACUC meeting recommending approval with his signature. Research begins after this final approval by the IO.

Some protocols may be selected for an additional level of review. Any protocol using dogs, cats, or nonhuman primates receives DOD-level review. Additionally, the Clinical Investigations Regulatory Office (CIRO) requires the forwarding of a copy of each approved DOD animal use protocol and routinely selects protocols for additional review. This lengthy process ensures that any proposed animal use has received due consideration before the animal use is allowed to proceed.

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1. Enrichment activities, including the exercise of lab dogs and activities enriching the psychological well being of nonhuman primates, are an example of refinement alternative activities at the institutional level.

2. This affects virtually every animal-use institution in the United States.

3. U.S. Army animal use regulation is the basis for all DOD policy. The Army Veterinary Corps is the DOD Executive Agent for animal use activities, hence all service regulations duplicate the Army's. Army animal use regulations are the "institutional policy" for DOD. Army Regulation 70-18, SECNAVINST 3900.38B, AFR 169-2, DARPAINST 18, DNAINST 3216.1B, and USUHSINST 3203 are the same regulation.

4. The "most stringent standard" rule implies that when conflict arises between the three sets of regulations (governmental, agency, and institutional), the most stringent standard will be applied.

5. MEDLINE is the National Library of Medicine's bibliographic database covering the fields of medicine, nursing, dentistry, veterinary medicine, health care systems, and other sciences. The MEDLINE file contains bibliographic citations and author abstracts from approximately 3,900 biomedical journals published in the United States and 70 other countries (GAO 1999, 9).

6. The Defense Technical Information Center is the government's central source for the sale of scientific, technical, and related business information produced for the U.S. government (GAO 1999, 11). This database also includes all publications authored by government agencies and individuals employed or contracted by the government.

APPENDIX D

COMMERCIAL MODEL MANUFACTURERS

Commercial model manufacturers cited in this thesis are listed in alphabetical order:

1. Ambu, Incorporated
   611 N. Hammonds Ferry Road
   Linthicum, MD 21090-1356
   Telephone: (800) 262-8462
   http://www.ambuusa.com/

2. Armstrong Medical Industries
   P.O. Box 700
   Lincolnshire, IL 60069
   Telephone: (847) 913-0101 or (800) 323-4220
   http://www.armstrongmedical.com/

3. Ethicon, Incorporated
   P.O. Box 151
   Somerville, NJ 08876
   Telephone: (800) 255-2500
   http://www.ethicon.com/

4. Gaumard Scientific
   14700 SW 136th Street
   Miami, FL 33199
   Telephone: (800) 882-6655
   http://www.gaumard.com/index.html

5. HT Medical Systems, Incorporated (Formerly High Techsplantations, Incorporated.)
   55 West Watkins Mills Road
   Gaithersburg, MD 20878
   Telephone: (301) 984-3706
   http://www.ht.com/

6. Laerdal Medical Corporation
   167 Myers Corners Road
   P.O. Box 1840
   Wappingers Falls, NY 12590-8840
   Telephone: (914) 297-7770 or (800) 431-1055
   http://www.laerdal.com/

7. Medical Education Technologies, Incorporated
   600 Fruitville Road
   Sarasota, FL 34232
   Telephone: (941) 377-5562
   http:// www.meti.com/

8. Medical Plastics Laboratory, Incorporated
226 FM 116
P.O. Box 38
Gatesville, TX 76528
Telephone: (254) 865-7221
http://www.medicalplastics.com/

9. MedSim Advanced Medical Simulations, Limited
3215 NW 10th Terrace
Suite 201
Ft. Lauderdale, FL 33309
Tel: (954) 563-0855
http://www.medsim.com/

10. MusculoGraphics, Incorporated
1840 Oak Avenue
Evanston, IL 60201
Telephone: (847) 866-1882
http://www.musculographics.com/

11. Pacific Research Laboratories, Incorporated (Sawbones)
P.O. Box 409
Vashon, WA 98070
Telephone: (206) 463-5551
http://www.sawbones.com/index.html

GLOSSARY

Alternative. Legally, alternatives to painful procedures performed on animals must by ascertained. In a broader sense, an alternative is any method by which the given animal use is reduced, refined (procedurally improved), or replaced. Common replacement alternatives in trauma training include virtual reality, computer simulation, cadavers, and plastic models. This concept is developed fully in appendix A.

Animal. Laboratory Animal. The broadest definition of the word "animal" is found in dictionaries which generally differentiate by kingdom (animals from plants) based on mobility and responsiveness to stimulus. The AWA (2-g) defines an animal as "any live or dead dog, cat, nonhuman primate, guinea pig, hamster, rabbit, or any other warm blooded animal, which is being used for research, testing, experimentation, or exhibition purposes or as a pet." Of note is the fact that this definition specifically excludes birds, rats, mice, and farm livestock. The most consistently used definition is offered by the PHS (1996, III): "Any live, vertebrate animal used or intended for use in research, training, experimentation, or biological testing or for related purposes."

Animal Facilitated Training. Animal Lab. Practicum. Animal facilitated training includes any training event that incorporates animal manipulations or procedures performed on animals as a training method. Animals are used as patient models during the conduct of trauma training.

Animal Rights. AR. Animal Rights is a personal value system or philosophical view based on the sanctity of life. Animal rights tenets hold that all life forms are of equal value and that one species cannot be ethically used by another for its own benefit or pleasure. This concept is developed fully in appendix B.

Animal Welfare. AW. Animal Welfare is an acknowledged responsibility for animal stewardship based on a value system recognizing species superiority within ethical bounds. The use of a phylogenically lower species by a higher one is considered acceptable, but animal stewardship is a responsibility. Human responsibilities for animal well being include proper housing, management, nutrition, healthcare, humane handling, and euthanasia when required (AVMA 2000, 71). Animal welfare tenets hold that unnecessary infliction of pain or distress is unethical. All animal use must therefore be justified. This concept is developed fully in appendix B.

Distress. From a physiological viewpoint, stress is an adaptive adrenal-cortical (hormonal) response to environmental change, attempting to maintain homeostasis. Stress has neither positive nor negative connotations and is entirely situation dependent. Distress can be defined simply as negatively perceived stress. Distress is an inferred aversive state based on a variety of behavioral, physiological, and psychological indices of an animal's inability to adapt to the effect of stressors and the attendant stress. Stressors that might induce distress include pain, handling (especially inappropriate handling), injury, anxiety, or fear. While handling a pet dog will cause stress (a physiological response), it will not cause distress (aversion). Conversely, petting an animal unaccustomed to human contact will cause distress. Caretakers have a responsibility to minimize distress in animals under their stewardship.

Euthanasia. The term euthanasia is derived from Greek meaning "good death," which implies death without pain, suffering, or distress. The American Veterinary Medical Association (1993, 229) defines euthanasia as the "act of inducing humane death in an animal. Euthanasia techniques should result in rapid unconsciousness followed by cardiac or respiratory arrest and ultimate loss of brain function." Euthanasia is employed as a means of relieving animal pain and suffering following experimental surgery and trauma labs when the tissue injury produced by the procedures performed might be expected to produce severe or prolonged distress. Such animals are euthanized before recovery from anesthesia.

Experiential Training. This is training in real conditions under the mentorship of qualified instructors. Examples of experiential training are medical internship and residency programs, training with industry programs, and ride along programs. This is the accepted optimal training modality for advanced skill development. Time is the greatest constraint on experiential training programs. Because training scenarios are unpredictable (experience is based on what comes through the door next), experiential training programs must last long enough to ensure exposure to the appropriate predetermined quantity and quality of training opportunities. Hence, emergency medicine residency programs last 3-4 years and surgical residency programs last up to 5 years. Experiential training programs are conducted at all levels of the healthcare chain, as time and resources permit.

Institutional Animal Care and Use Committee. IACUC. An IACUC is a locally appointed committee with the responsibility to oversee and evaluate the institution's animal use program, procedures, and facilities in order to ensure that they are consistent with animal use regulation (NRC 1996, 9). Within the DOD an IACUC consists of at least 5 voting members to include a chairman, a veterinarian, a scientific member, a nonscientific member, a nonaffiliated community member, and one nonvoting recorder. Their responsibilities include semi-annual review of the Institutional Animal Use Program, recurrent facility inspections, protocol review, animal use record keeping, suspension of questionable activities, and production of reports which the IO forwards to inspecting agencies (USDA, PHS, Congress, AAALAC). The IACUC is appointed by, and reports to, the Institutional Official (IO).

Institutional Official. IO. The individual within the institution who is legally responsible for the conduct of the institution's animal care and use program. The PHS (1996) defines an IO as the "individual who signs, and has the authority to sign the institution's Assurance, making a commitment on behalf of the institution that the requirements of this [PHS] Policy will be met." This individual makes assurances to the institution, the government, and the public that good faith efforts are made to ensure animal welfare. He is the final approving authority for the animal use program, its policies, and the protocols approved. The IO approves final disposition, based on IACUC recommendations, of animal use matters. He has veto authority over the IACUC, but cannot approve without their recommendation. In civilian animal use programs, this individual would likely be the Dean of Research for the university. In the military, the IO is usually the unit commander or his deputy.

Institutional Animal Use Program. As a document, the animal use program is a single source that outlines the sum total of the institution's animal use activities to include identification of key personnel and points of contact, policies for animal care and use, descriptions of the

nature of animal use activities, policies for protocol submission and review, animal care facility descriptions, oversight and accreditation history, qualifications and training of personnel, and statements of expected standards. As a program, it implements the policies described in the document. The IACUC is responsible for approval and oversight of the program; the IO is responsible for its implementation.

Investigator. Principle Investigator. PI. An investigator is any individual involved in the conduct of research, development, testing, or evaluation involving laboratory animals. The primary investigator is the individual who is responsible and accountable for the protocol and any animals associated with it. At civilian institutions, this would be the senior researcher over a project, inevitably the researcher who has been named recipient of funding grants. In military trauma training, this would be the course coordinator. The primary investigator is responsible for authorship of the protocol for the given animal use and for conduct of training in accordance with that protocol.

Pain. The International Association for the Study of Pain defines pain as an "unpleasant sensory and emotional experience associated with actual or potential tissue damage" (ISAP 1979, 249). Pain is the conscious perception of a noxious (nociceptive) stimulus. Alleviation of pain (a perception) is accomplished via the disassociation of the stimulus from the conscious brain. This is the basis of anesthesia. While humans have experienced and understand pain, the recognition of animal pain is difficult. The defense mechanisms of animals minimize outward displays of pain-related behavior (Hall 1992; Heavner 1992; and Wall 1992). The elimination of avoidable pain is a human responsibility under Animal Welfare. This leads to the PHS recommendation that any procedure that might be considered painful in humans also be considered painful in animals. Thus, any procedure exceeding transient discomfort, such as experienced by a needle prick or injection, necessitates the alleviation of pain (NRC 1996, 64-65).

Protocol. Animal Use Protocol. A protocol seeking approval to use animals in an investigation is submitted by the investigator to the IACUC. The protocol provides details of the proposed animal use including descriptions of the animal use, justification, alternatives sought, and methods for elimination of any anticipated animal pain and distress. All uses of animals by institutional employees must be conducted under an approved protocol. On approval, the protocol becomes a contract between the IACUC, providing oversight of the event, and the investigator, conducting the event. This definition is described fully in appendix C.

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AWA. *See* Animal Welfare Regulations.

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